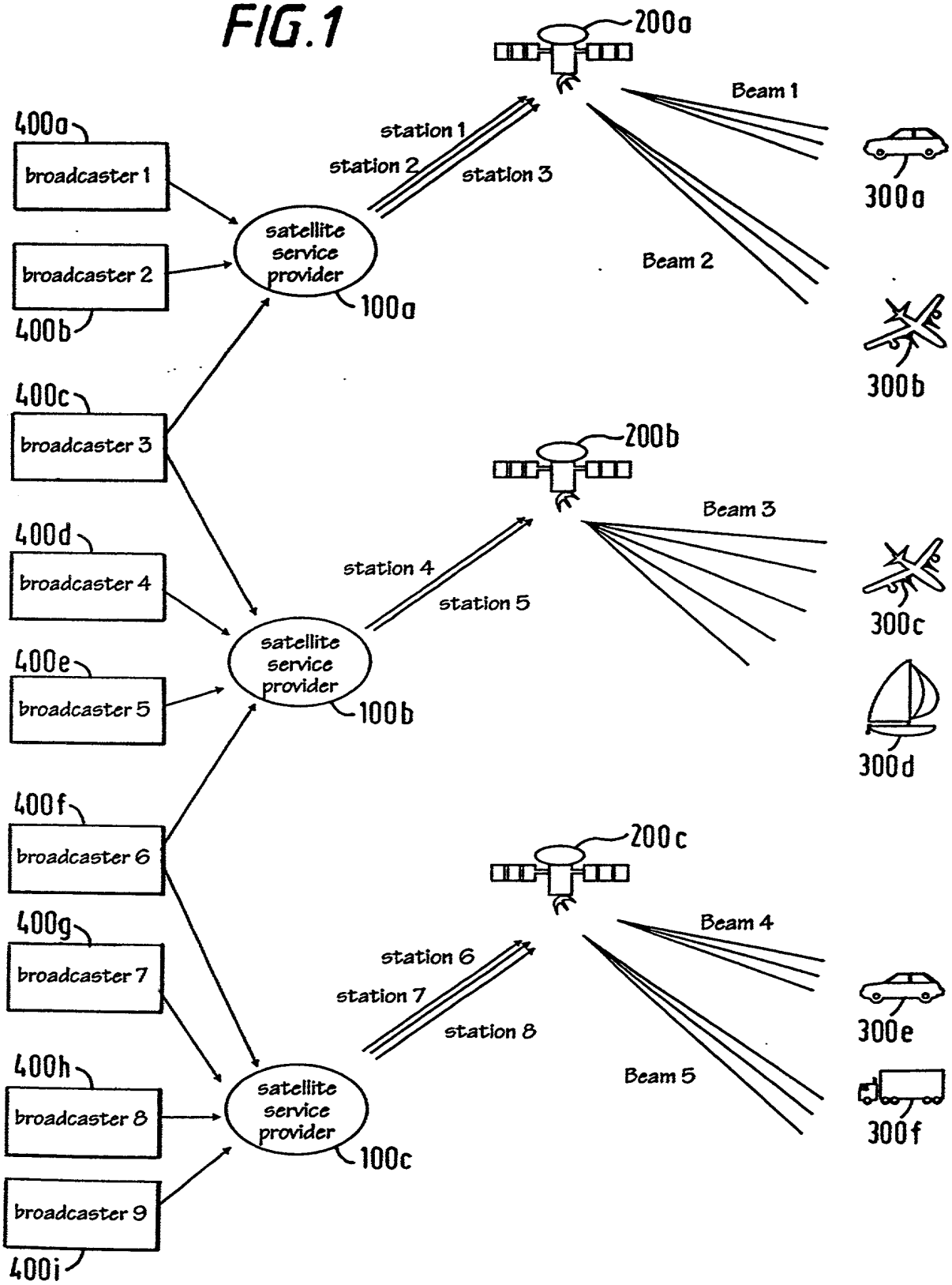
FIG.1


200a
Beam 1
station 1
station 2
station 3
400a
broadcaster 1
broadcaster 2
400b
satellite service provider
100a
Beam 2
300a
300b
400c
broadcaster 3
200b
Beam 3
400d
broadcaster 4
station 4
station 5
400e
broadcaster 5
satellite service provider
100b
300c
300d
400f
broadcaster 6
200c
Beam 4
400g
broadcaster 7
station 6
station 7
station 8
400h
broadcaster 8
satellite service provider
100c
Beam 5
300e
300f
broadcaster 9
400i

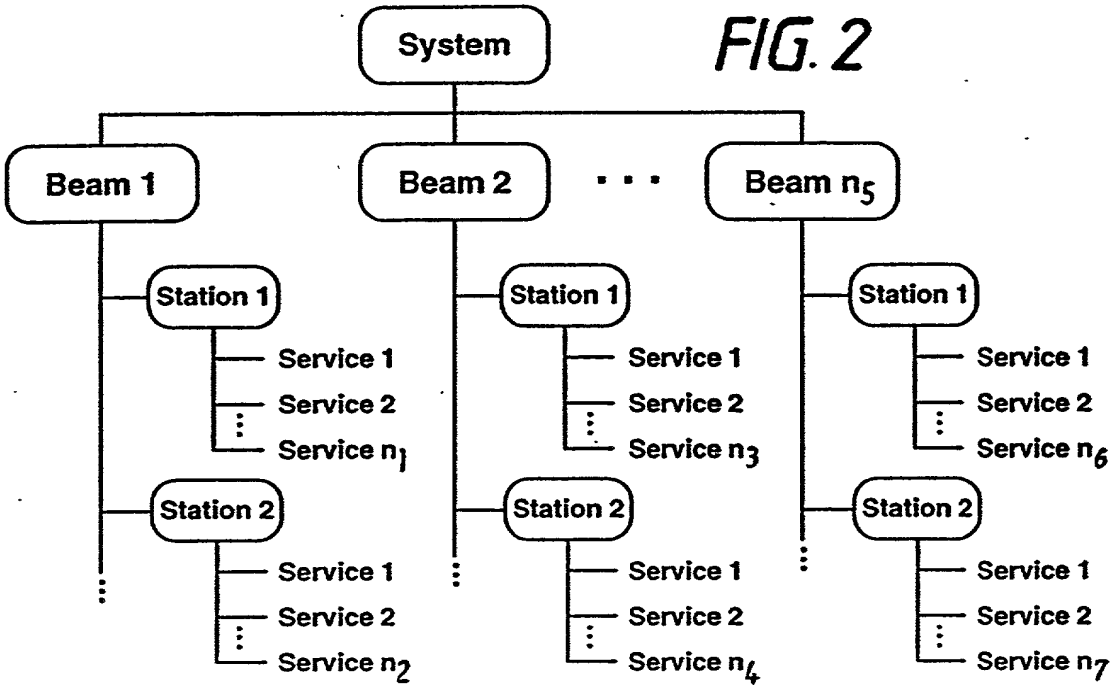

System
Beam 1
Beam 2
Beam n_5
Station 1
Station 2
Service 1
Service 2
Service n_1
Service n_2
Service n_3
Service n_4
Service n_6
Service n_7

FIG. 2

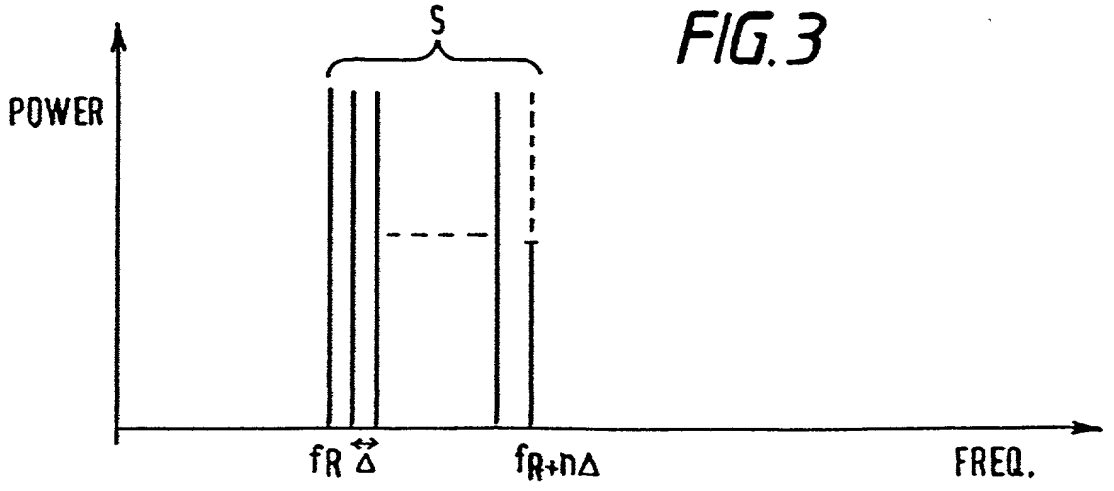
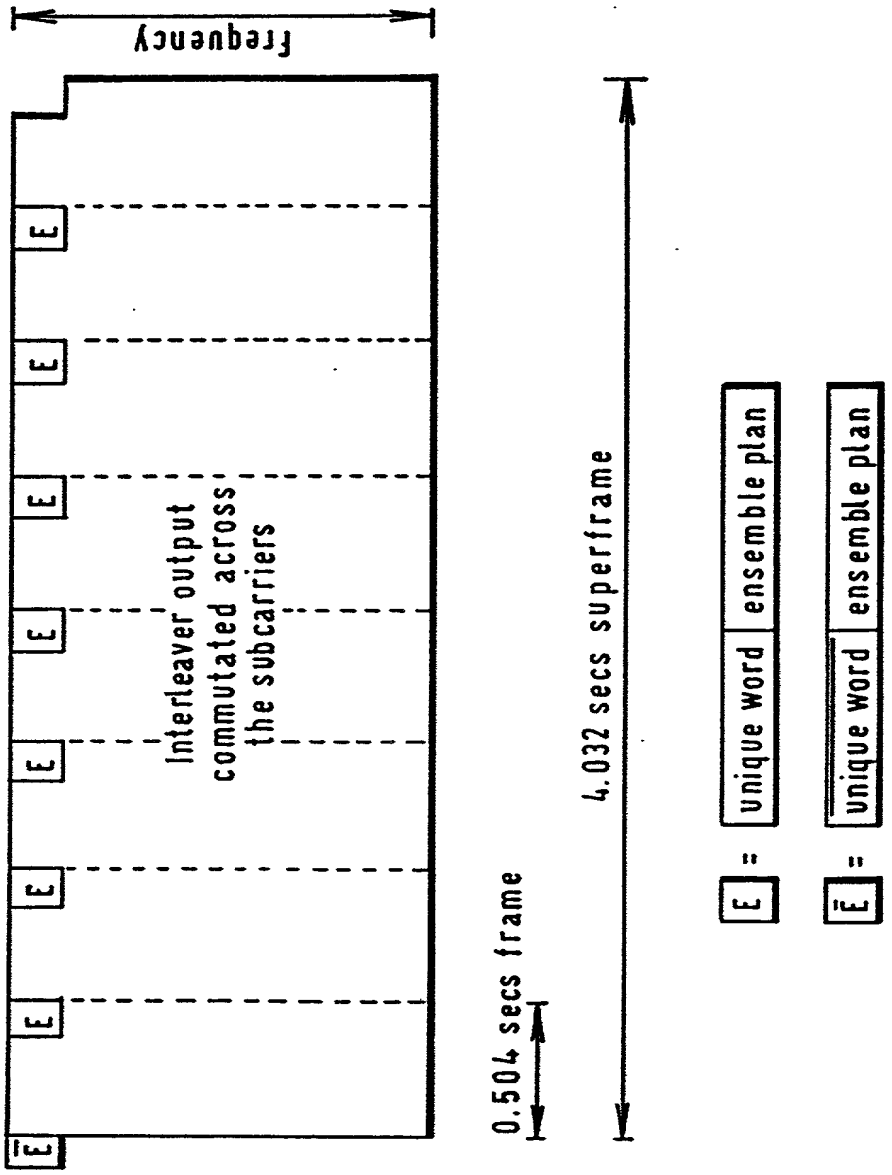

S
POWER
f_R
Δ
$f_{R+n\Delta}$
FREQ.

FIG. 3

FIG. 4


frequency
Interleaver output commutated across the subcarriers
E
0.504 secs frame
4.032 secs superframe
E = unique word | ensemble plan
Ē = unique word | ensemble plan

a) format of the multiplexed B6 stream

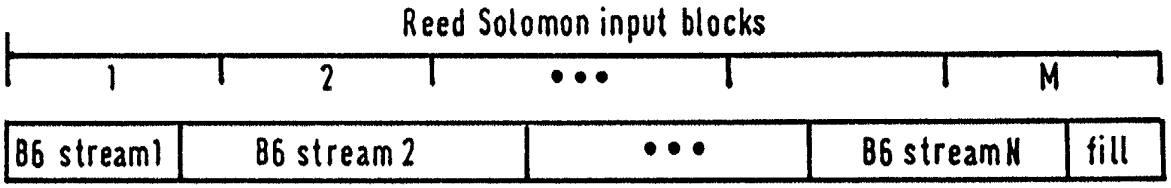


FIG.5

b) format of the multiplexed B4 stream

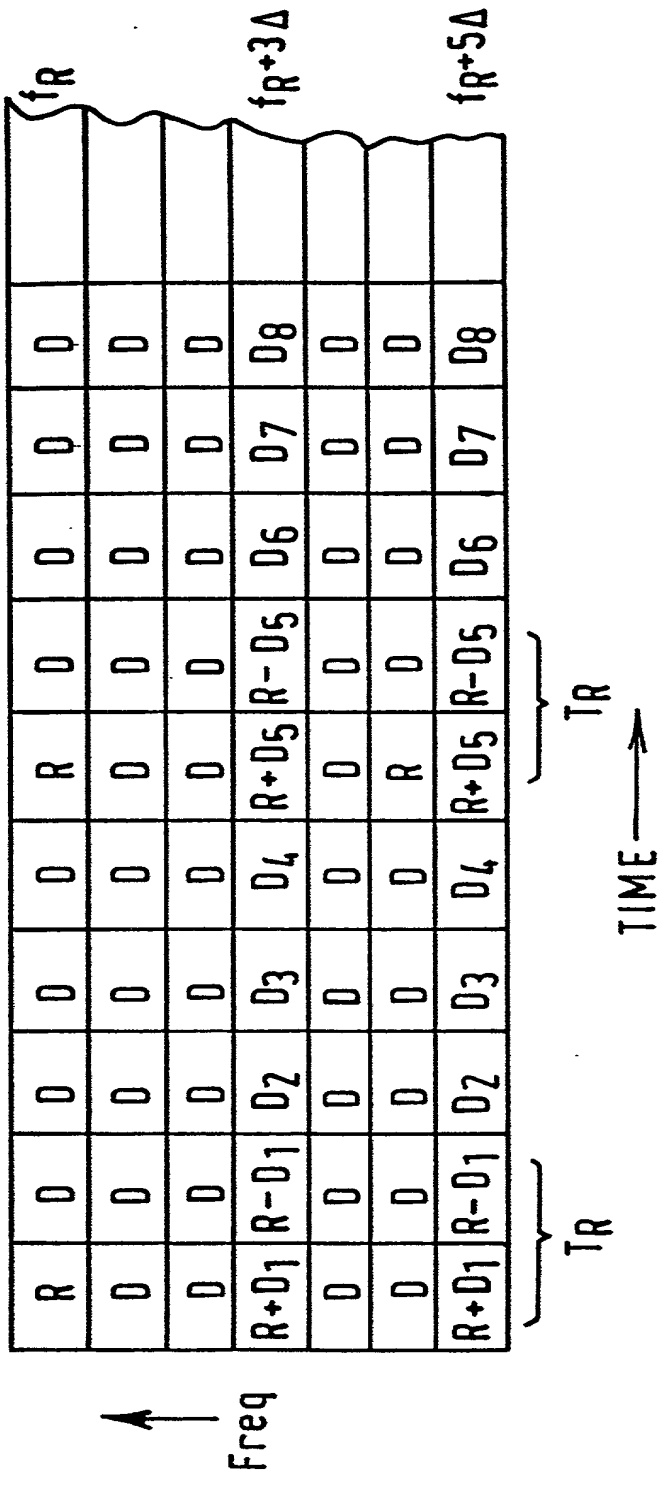
c) format of the multiplexed services stream

FIG.6a

ensemble configur.	transmitted subcarriers MR=main ref; R,r=ref; D,d=data uppercase=full, lowercase=half																
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0	MR	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
1	MR	d	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
2	MR	D	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
3	MR	D	d	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
4	MR	D	D	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
5	MR	D	D	r	.	.	.	.	.	.	.	.	.	.	.	.	.	
6	MR	D	D	R	.	.	.	.	.	.	.	.	.	.	.	.	.	
7	MR	D	D	R	d	.	.	.	.	.	.	.	.	.	.	.	.	
8	MR	D	D	R	D	.	.	.	.	.	.	.	.	.	.	.	.	
9	MR	D	D	R	D	d	.	.	.	.	.	.	.	.	.	.	.	
10	MR	D	D	R	D	D	.	.	.	.	.	.	.	.	.	.	.	
11	MR	D	D	R	D	D	r	.	.	.	.	.	.	.	.	.	.	
12	MR	D	D	R	D	D	R	.	.	.	.	.	.	.	.	.	.	
13	MR	D	D	R	D	D	R	d	.	.	.	.	.	.	.	.	.	
14	MR	D	D	R	D	D	R	D	.	.	.	.	.	.	.	.	.	
15	MR	D	D	R	D	D	R	D	d	.	.	.	.	.	.	.	.	
16	MR	D	D	R	D	D	R	D	D	.	.	.	.	.	.	.	.	
17	MR	D	D	R	D	D	R	D	D	r	.	.	.	.	.	.	.	
18	MR	D	D	R	D	D	R	D	D	R	.	.	.	.	.	.	.	
19	MR	D	D	R	D	D	R	D	D	R	d	.	.	.	.	.	.	
20	MR	D	D	R	D	D	R	D	D	R	D	.	.	.	.	.	.	
21	MR	D	D	R	D	D	R	D	D	R	D	d	.	.	.	.	.	
22	MR	D	D	R	D	D	R	D	D	R	D	D	.	.	.	.	.	
23	MR	D	D	R	D	D	R	D	D	R	D	D	r	.	.	.	.	
24	MR	D	D	R	D	D	R	D	D	R	D	D	R	.	.	.	.	
25	MR	D	D	R	D	D	R	D	D	R	D	D	R	d	.	.	.	
26	MR	D	D	R	D	D	R	D	D	R	D	D	R	D	.	.	.	
27	MR	D	D	R	D	D	R	D	D	R	D	D	R	D	d	.	.	
28	MR	D	D	R	D	D	R	D	D	R	D	D	R	D	D	.	.	
29	MR	D	D	R	D	D	R	D	D	R	D	D	R	D	D	r	.	
30	MR	D	D	R	D	D	R	D	D	R	D	D	R	D	D	R	.	
31	MR	D	D	R	D	D	R	D	D	R	D	D	R	D	D	R	d	
32	MR	D	D	R	D	D	R	D	D	R	D	D	R	D	D	R	D	

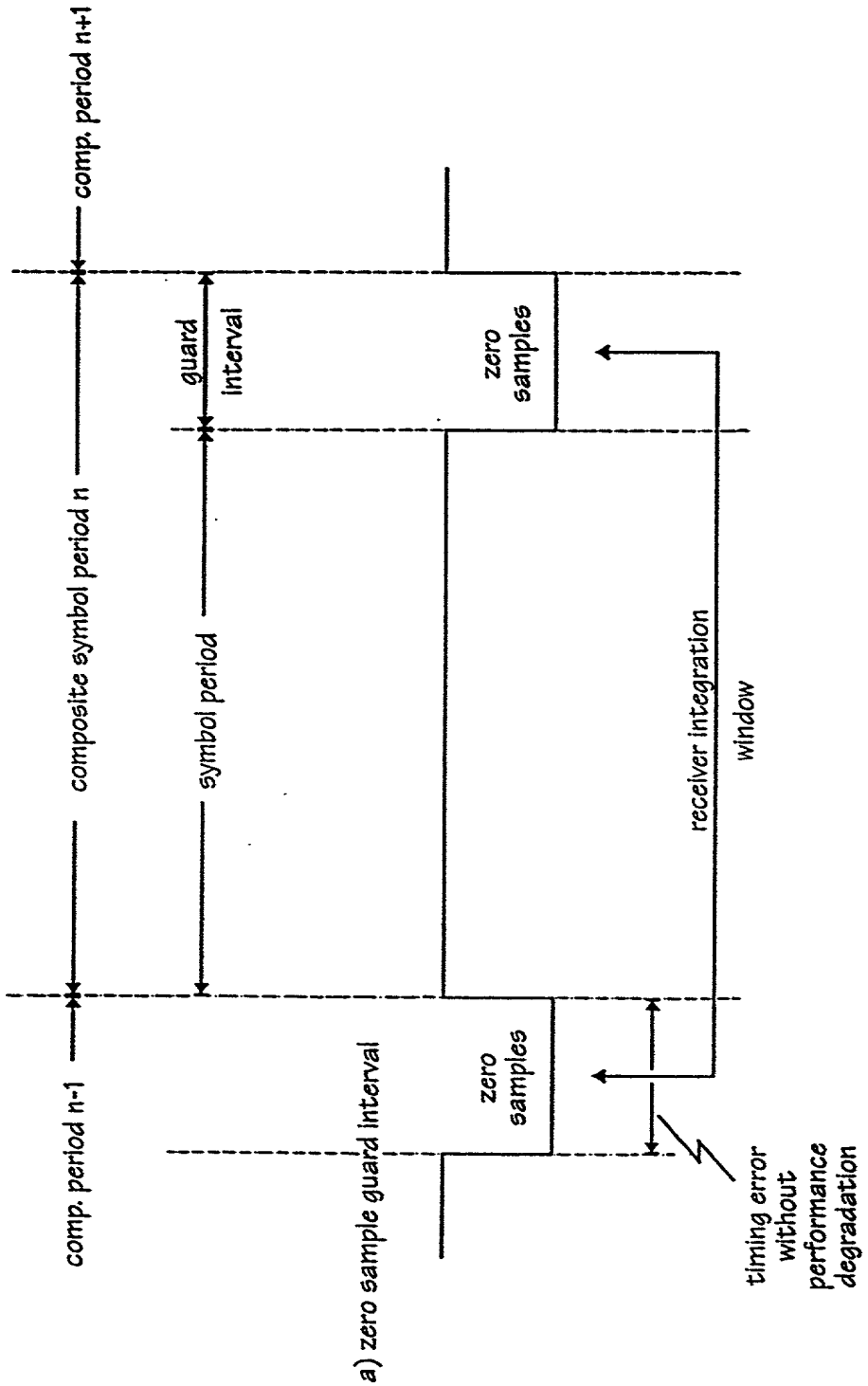
→ Frequency

FIG. 6b


f_R
$f_R+3\Delta$
$f_R+5\Delta$
R
D
$R+D_1$
$R-D_1$
D_2
D_3
D_4
$R+D_5$
$R-D_5$
D_6
D_7
D_8
T_R
T_R
TIME
Freq

Page 7 of 30

FIG. 7



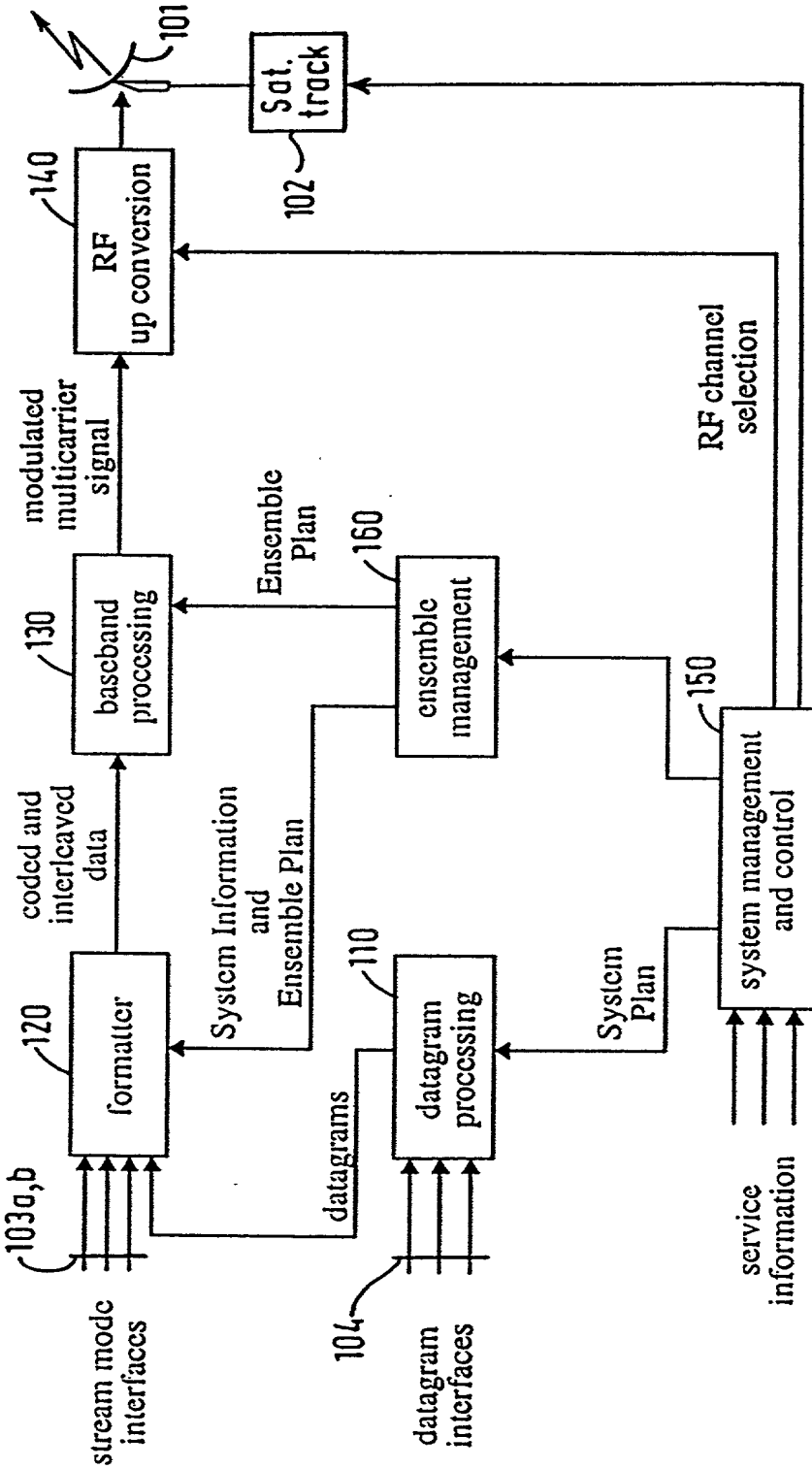
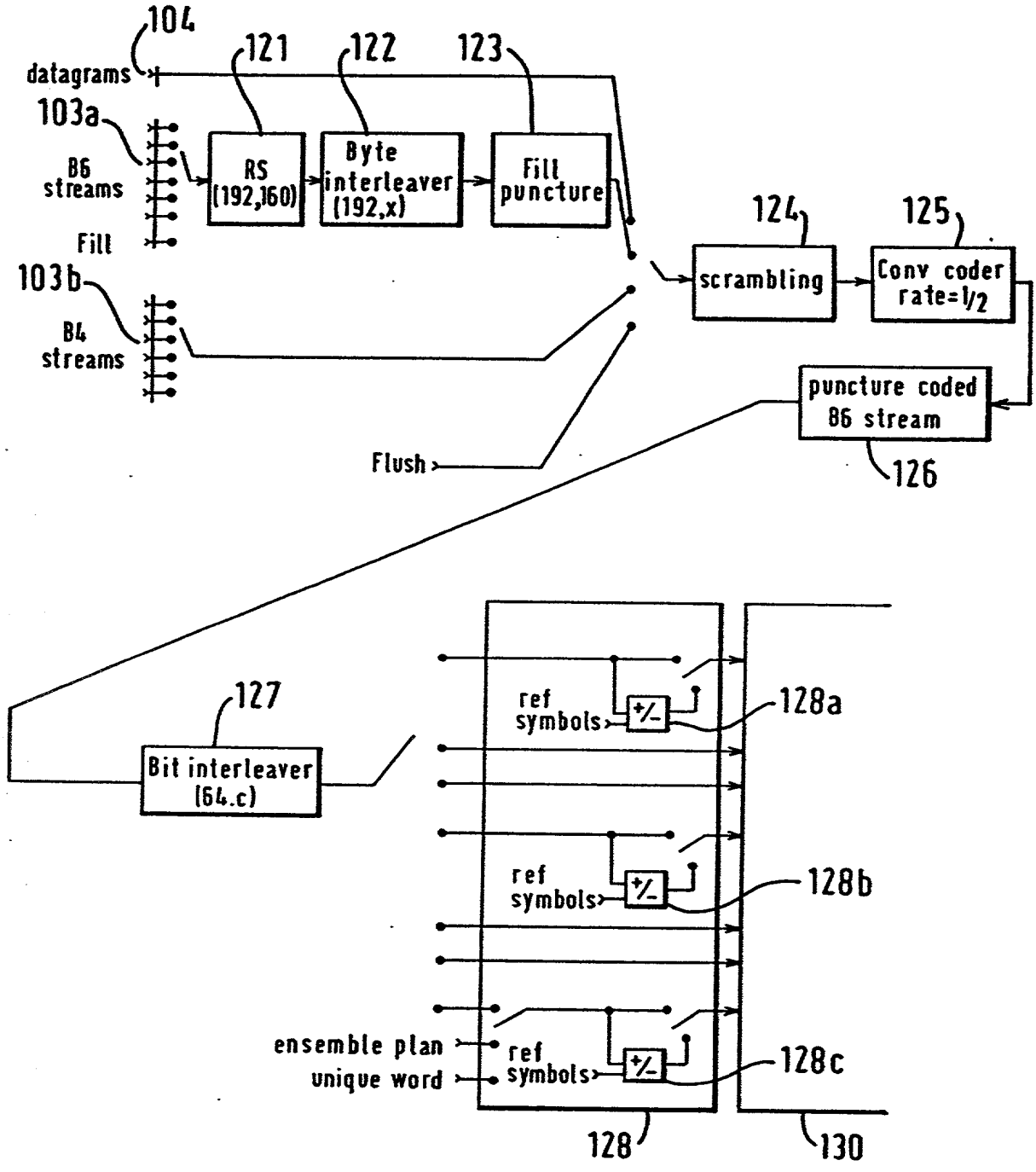

101
Sat. track
102
140
RF up conversion
modulated multicarrier signal
RF channel selection
Ensemble Plan
160
130
baseband processing
ensemble management
150
coded and interleaved data
System Information and Ensemble Plan
110
120
formatter
datagram processing
system management and control
System Plan
operator interface
datagrams
103a,b
104
stream mode interfaces
datagram interfaces
service information

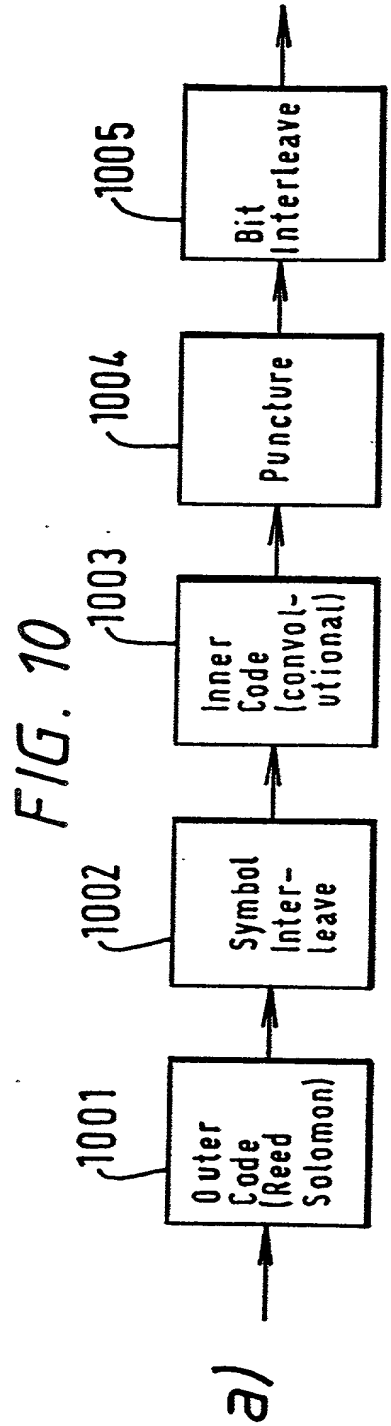
FIG. 8

FIG. 9


104
datagrams
121
122
123
103a
B6 streams
Fill
103b
B4 streams
RS (192,160)
Byte interleaver (192,x)
Fill puncture
124
125
scrambling
Conv coder rate=1/2
puncture coded B6 stream
126
Flush
127
Bit interleaver (64.c)
ref symbols
+/-
128a
128b
128c
ensemble plan
unique word
128
130

Page 6 of 6

FIG. 10



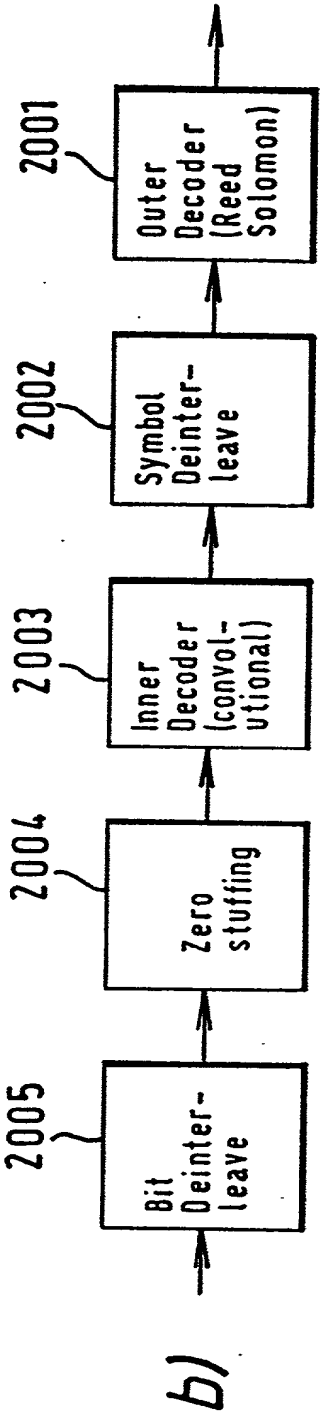


FIG. 11

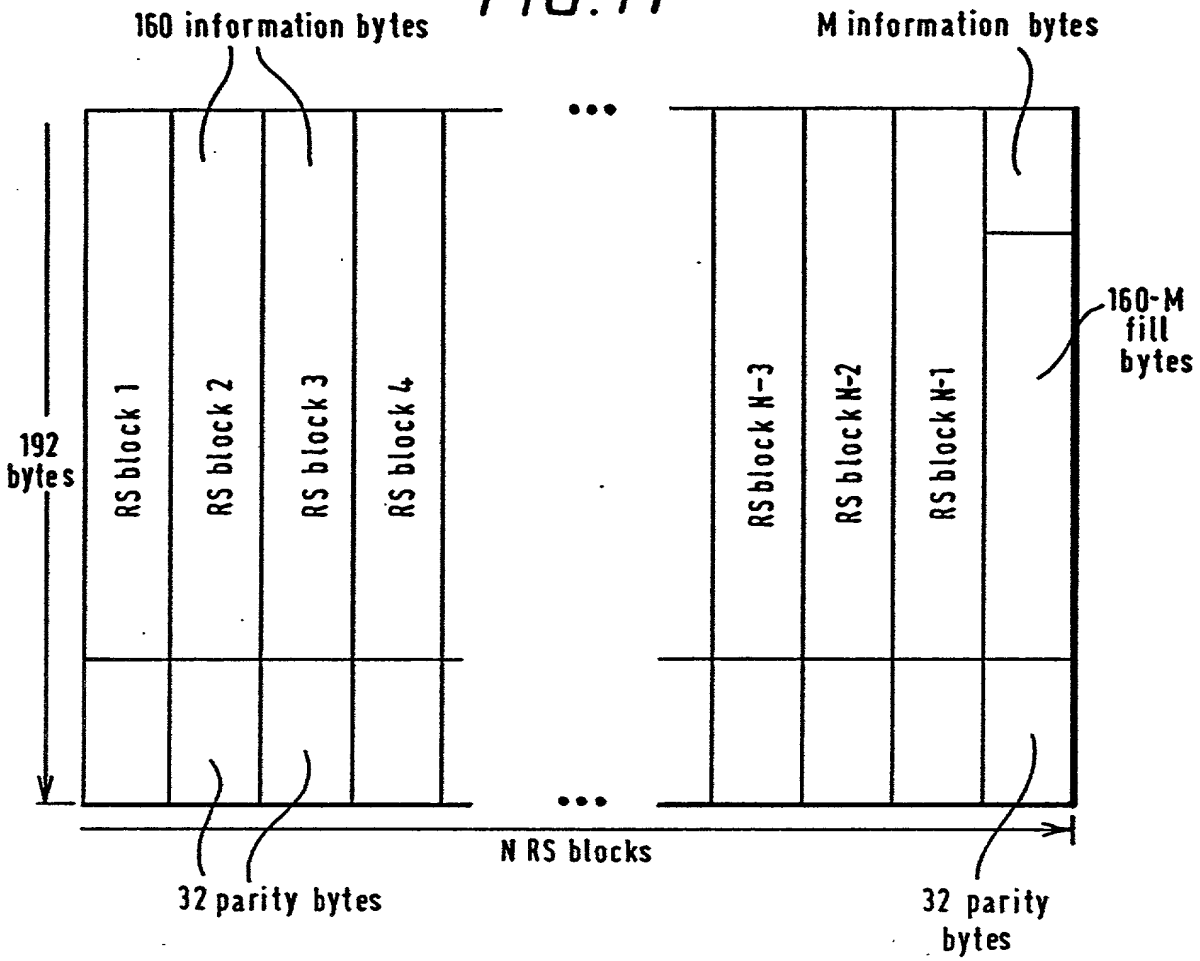

160 information bytes
M information bytes
192 bytes
RS block 1
RS block 2
RS block 3
RS block 4
RS block N-3
RS block N-2
RS block N-1
160-M fill bytes
N RS blocks
32 parity bytes
32 parity bytes

FIG. 12

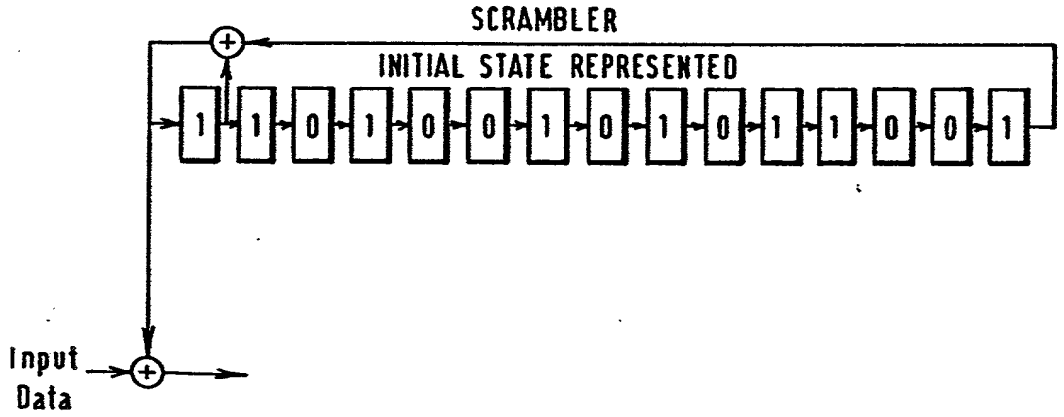
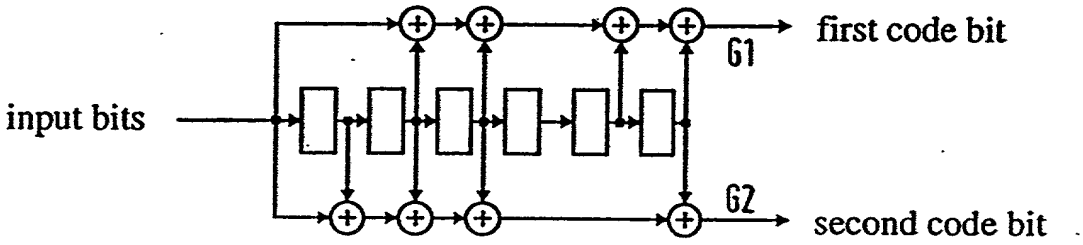

SCRAMBLER
INITIAL STATE REPRESENTED
1 1 0 1 0 0 1 0 1 0 1 1 0 0 1
Input Data

FIG. 13



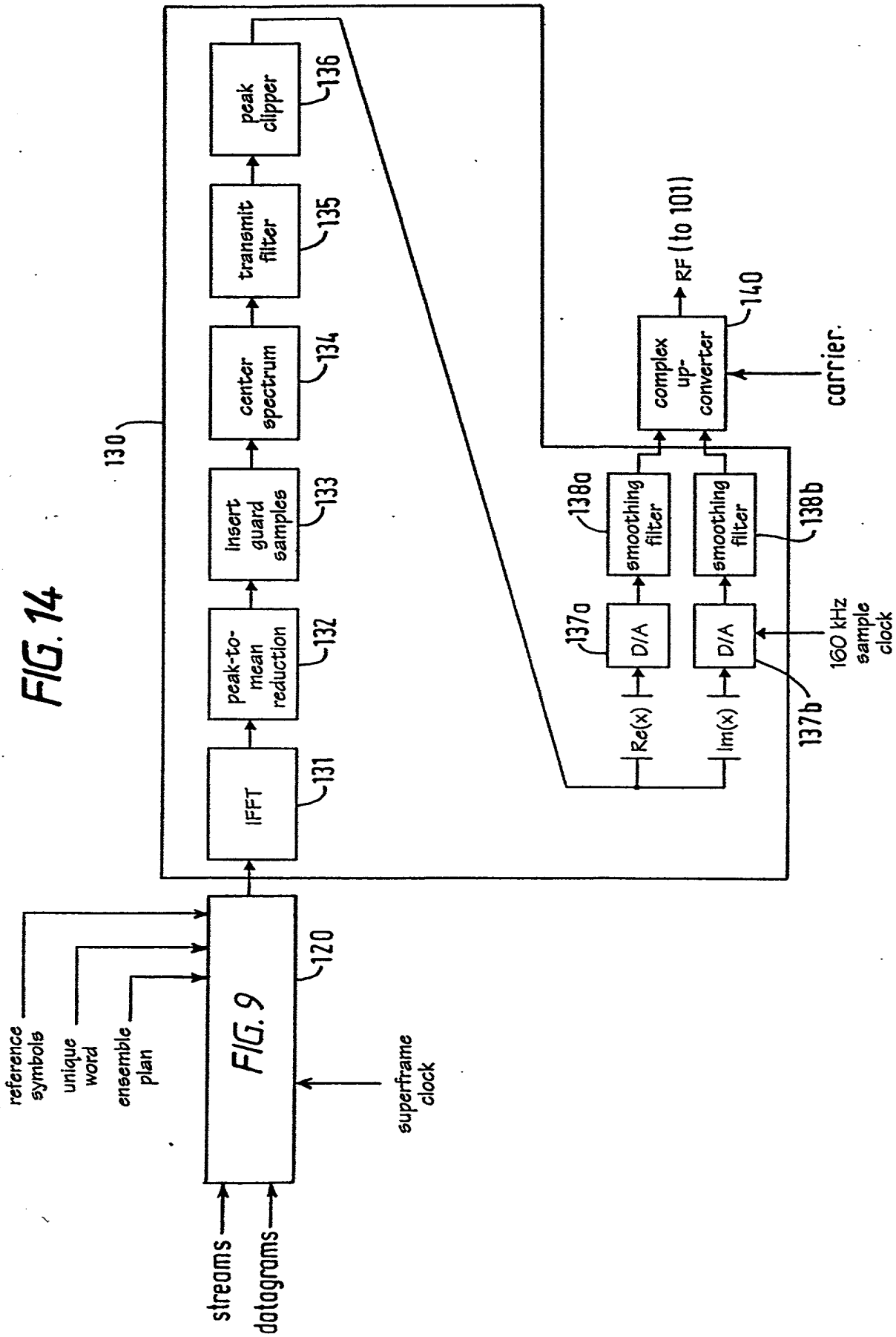

streams
datagrams
reference symbols
unique word
ensemble plan
FIG. 9
120
superframe clock
130
IFFT
131
peak-to-mean reduction
132
insert guard samples
133
center spectrum
134
transmit filter
135
peak clipper
136
Re(x)
Im(x)
137a
137b
D/A
D/A
160 kHz sample clock
138a
138b
smoothing filter
smoothing filter
complex up-converter
140
carrier
RF (to 101)

FIG. 14

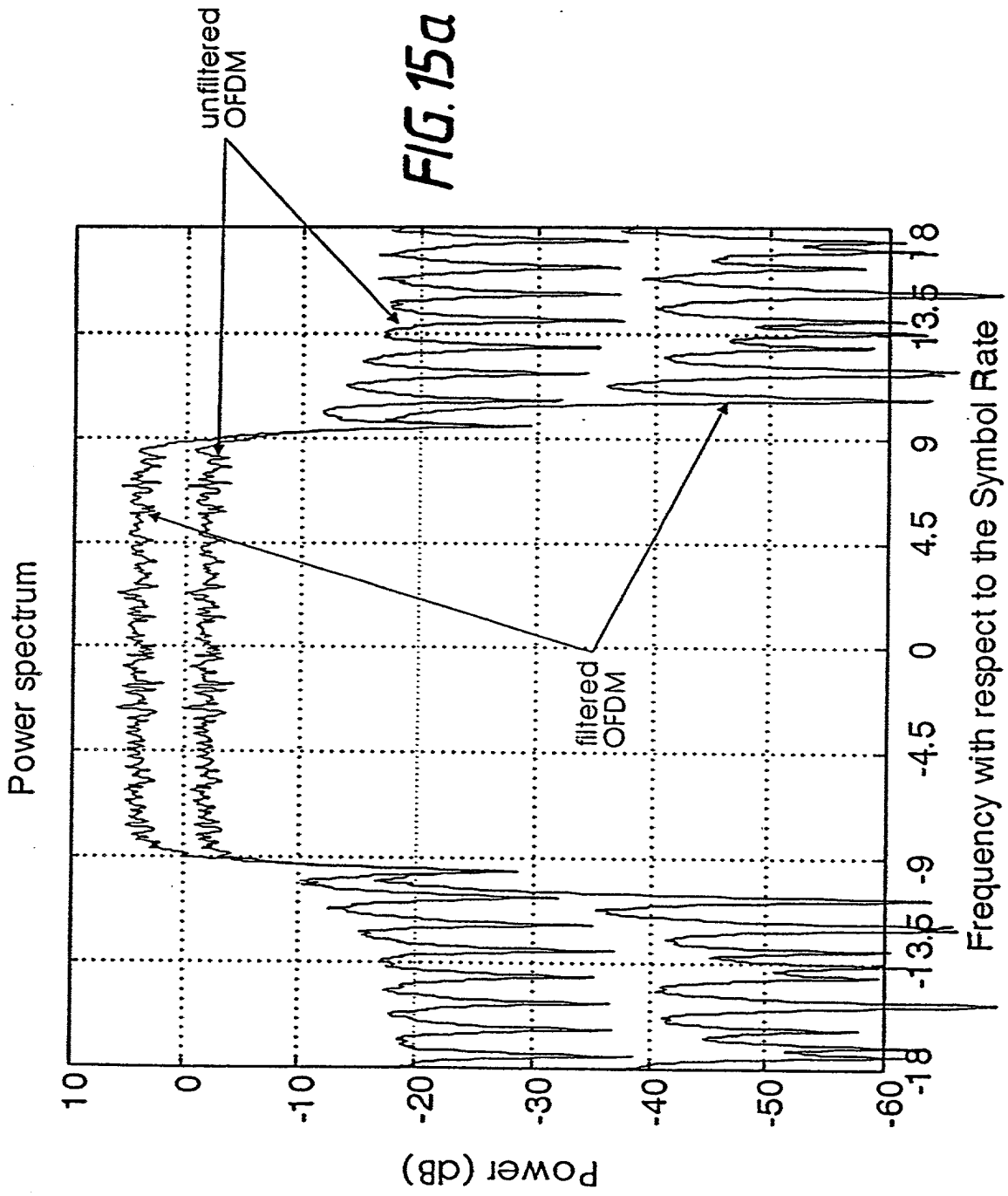
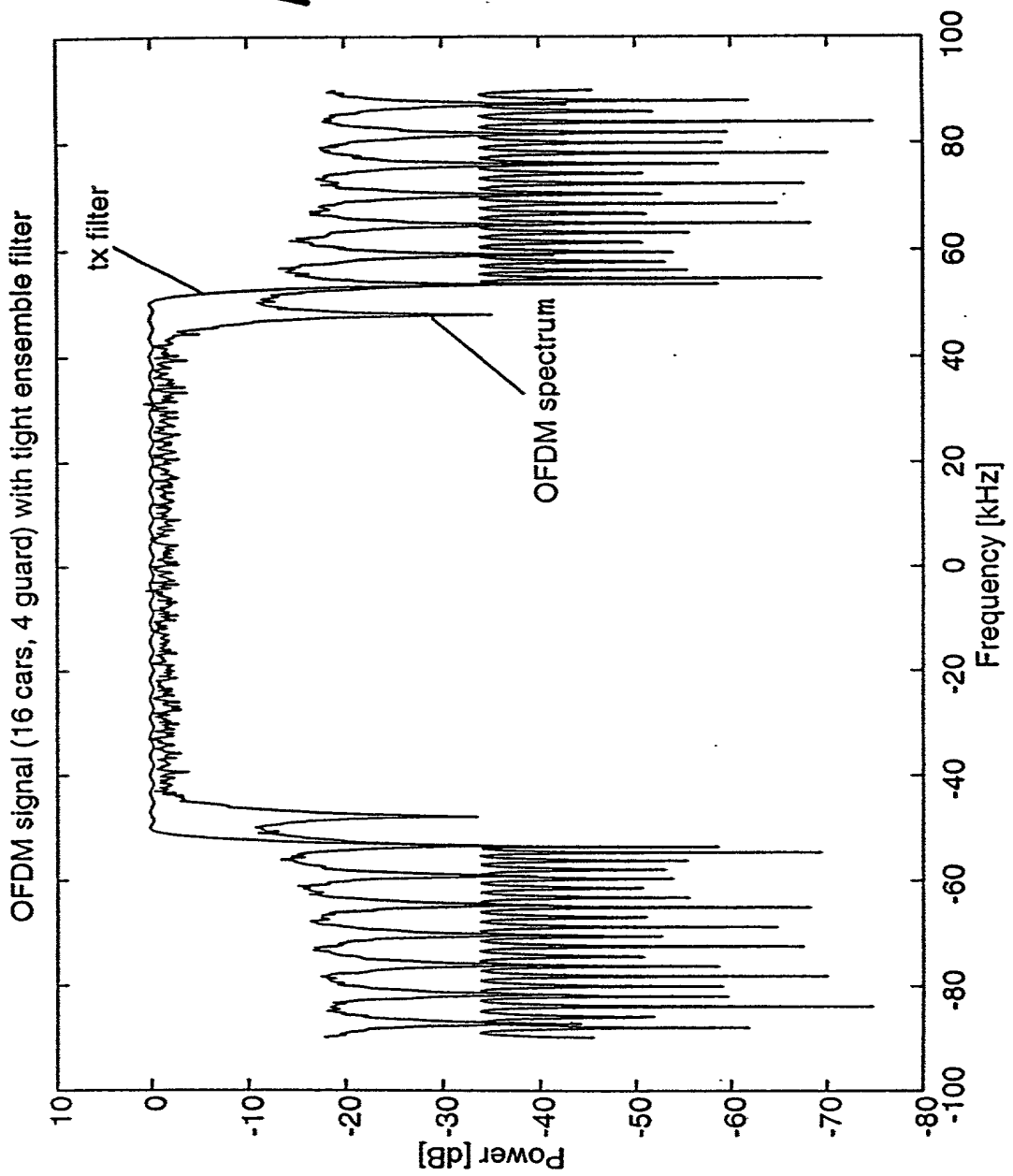

Power spectrum
unfiltered OFDM
filtered OFDM
Power (dB)
10
0
-10
-20
-30
-40
-50
-60
-18
-13.5
-9
-4.5
0
4.5
9
13.5
18
Frequency with respect to the Symbol Rate

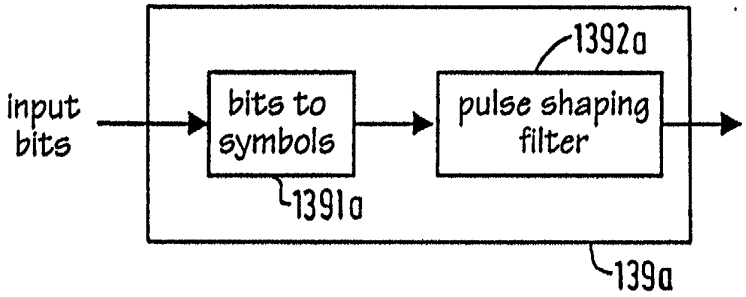
FIG. 15a

FIG.15b


OFDM signal (16 cars, 4 guard) with tight ensemble filter
tx filter
OFDM spectrum
Power [dB]
Frequency [kHz]
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-100
-80
-60
-40
-20
0
20
40
60
80
100

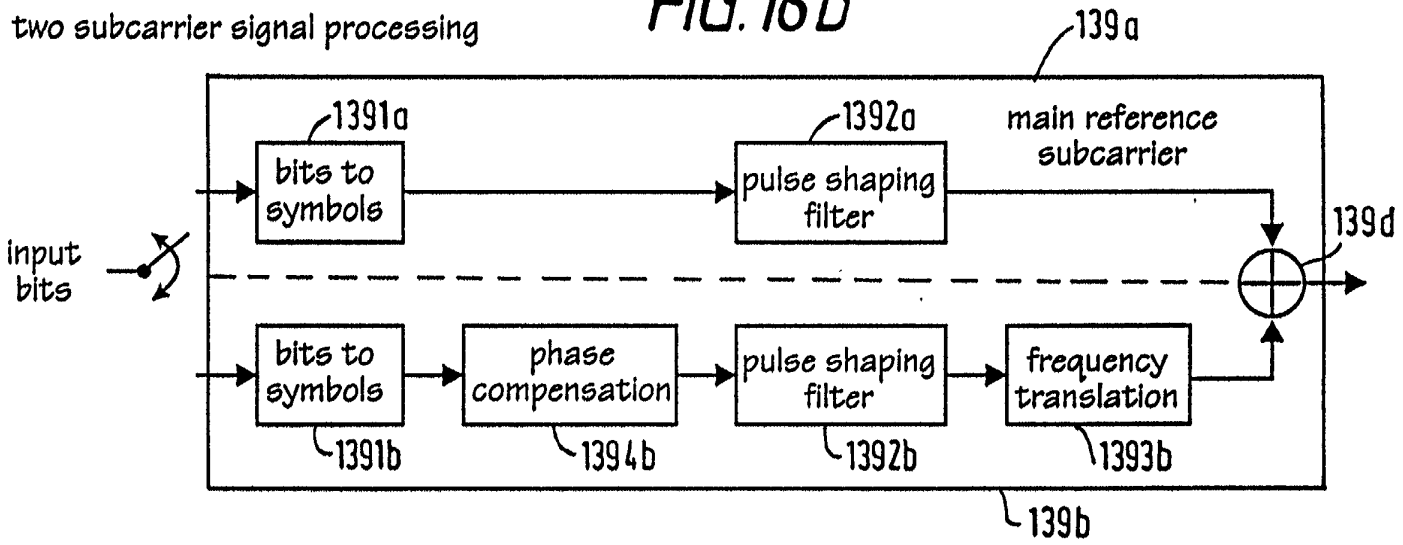
single subcarrier signal processing

FIG. 16a



two subcarrier signal processing

FIG. 16b



three subcarrier signal processing

FIG. 16c

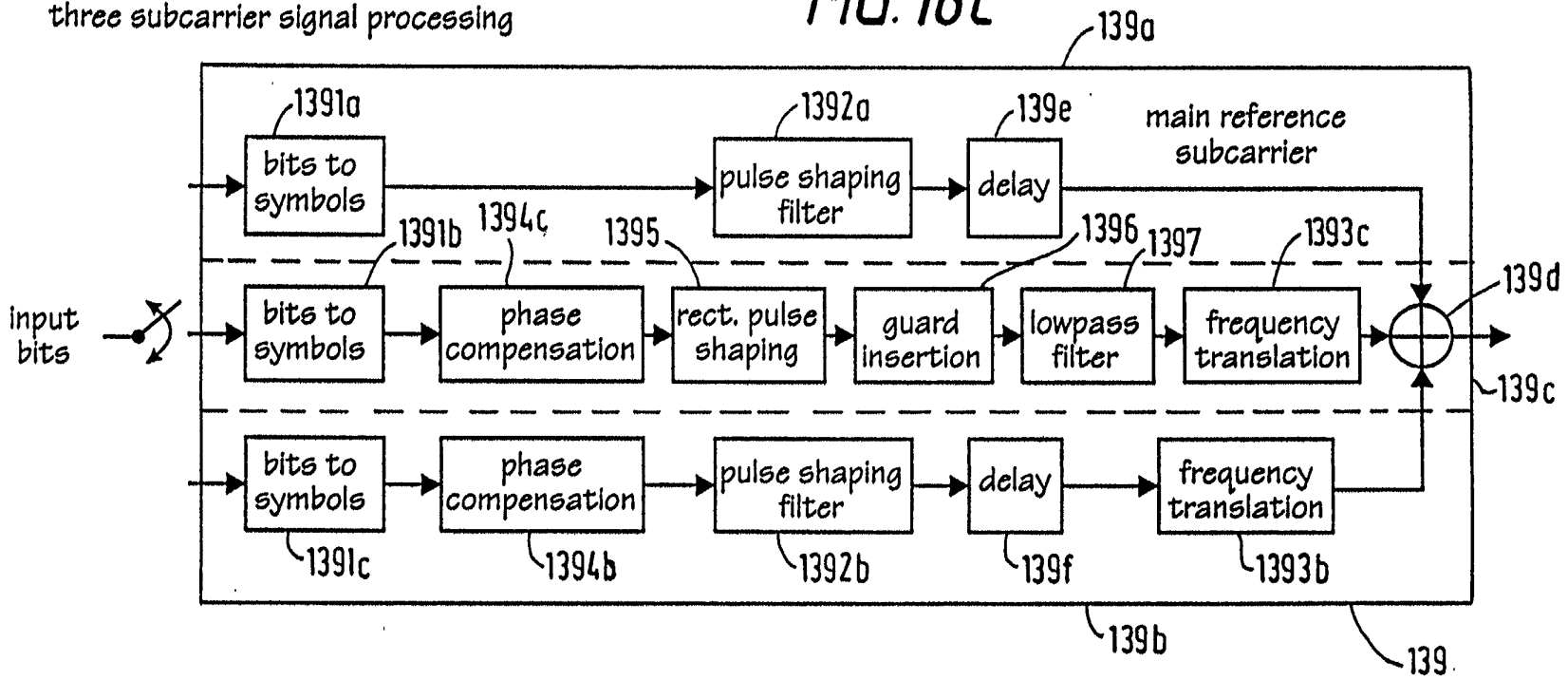
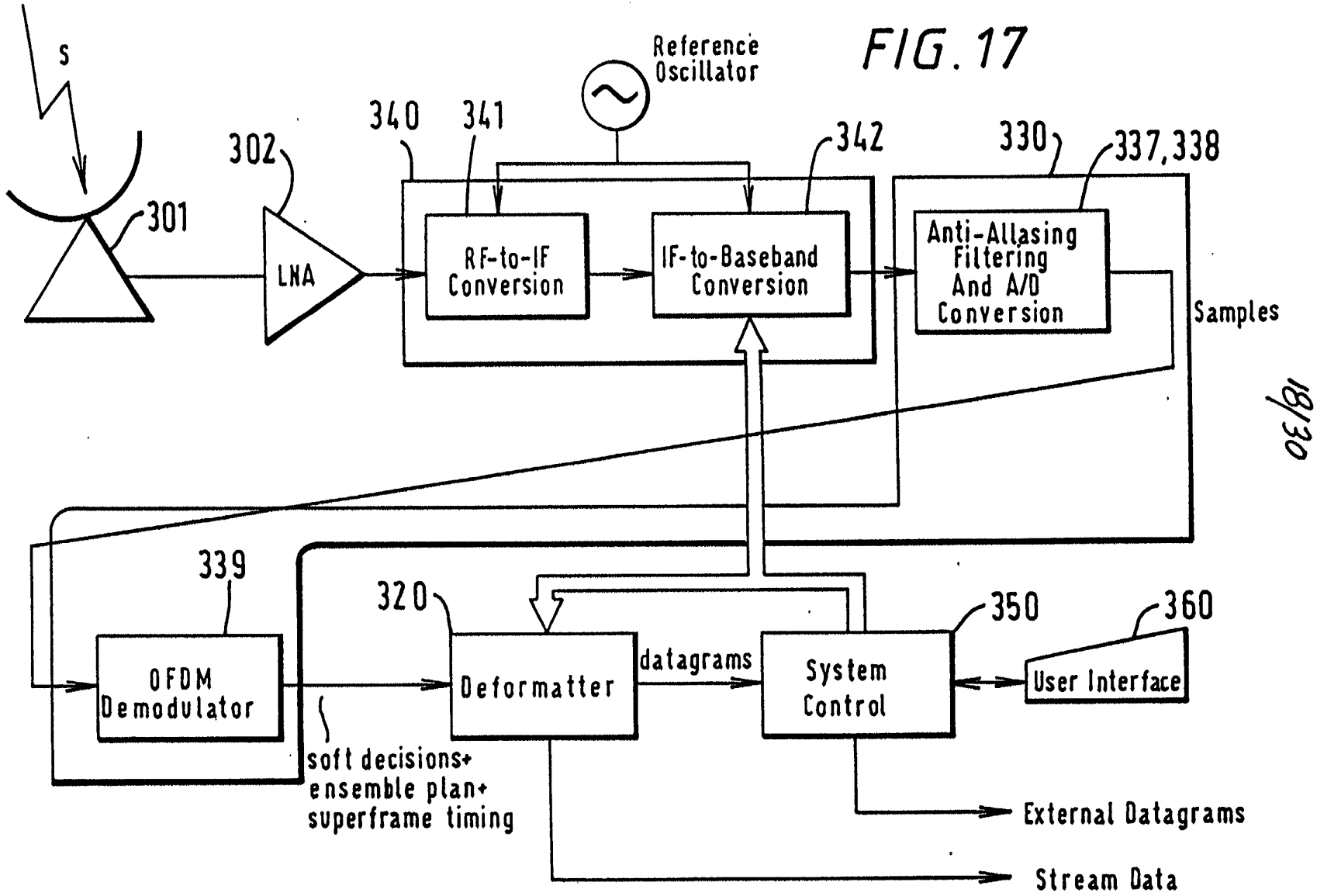


FIG. 17


S
301
302
LNA
340
341
Reference Oscillator
342
RF-to-IF Conversion
IF-to-Baseband Conversion
330
337,338
Anti-Allasing Filtering And A/D Conversion
Samples
339
OFDM Demodulator
320
Deformatter
datagrams
System Control
350
360
User Interface
soft decisions+ ensemble plan+ superframe timing
External Datagrams
Stream Data

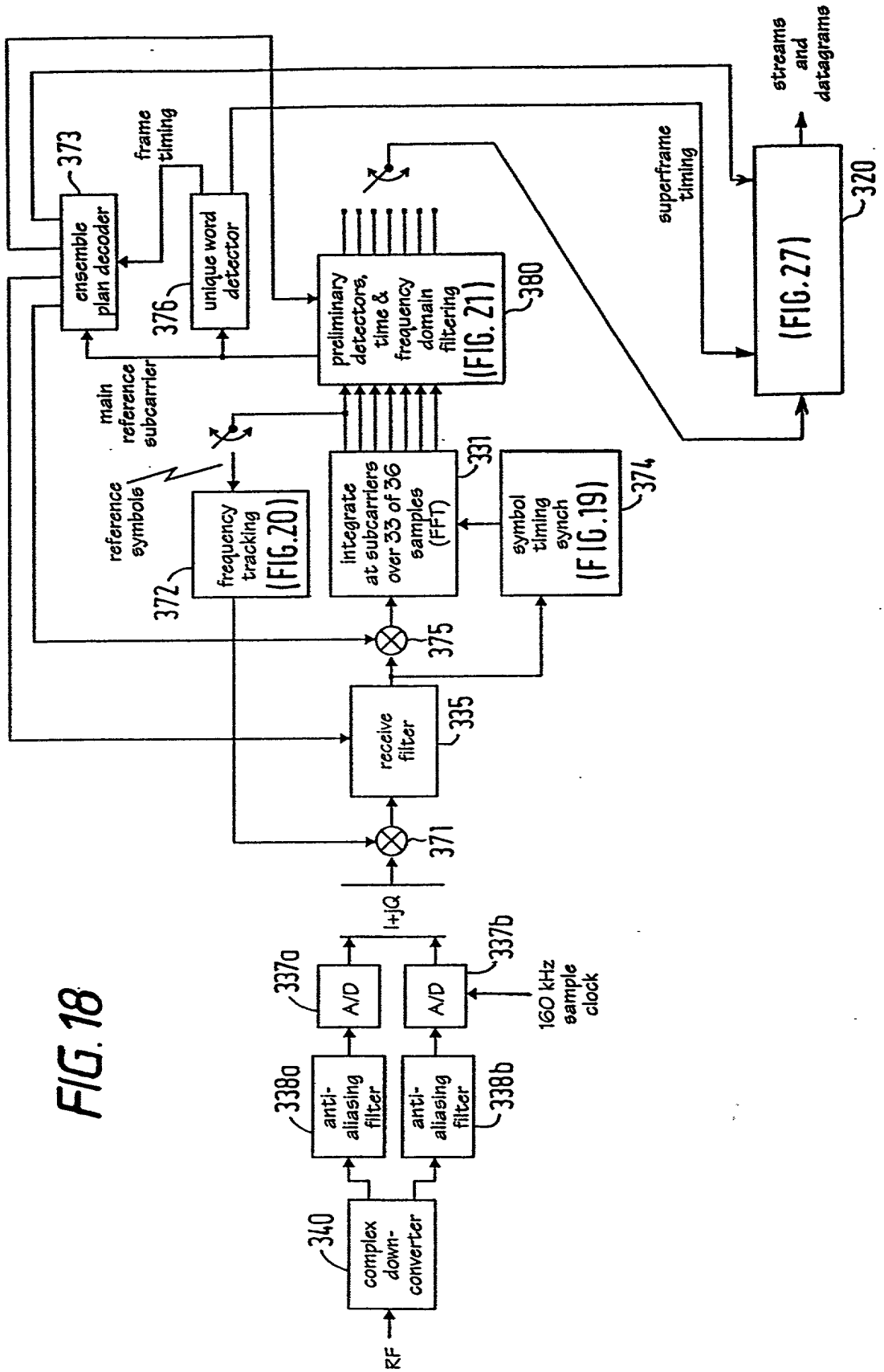

RF
complex down-converter
340
anti-aliasing filter
338a
anti-aliasing filter
338b
A/D
337a
A/D
337b
160 kHz sample clock
I+jQ
371
receive filter
335
375
frequency tracking (FIG.20)
372
reference symbols
main reference subcarrier
integrate at subcarriers over 33 of 36 samples (FFT)
331
symbol timing synch (FIG.19)
374
preliminary detectors, time & frequency domain filtering (FIG. 21)
380
unique word detector
376
ensemble plan decoder
373
frame timing
superframe timing
(FIG. 27)
320
streams and datagrams

FIG. 18

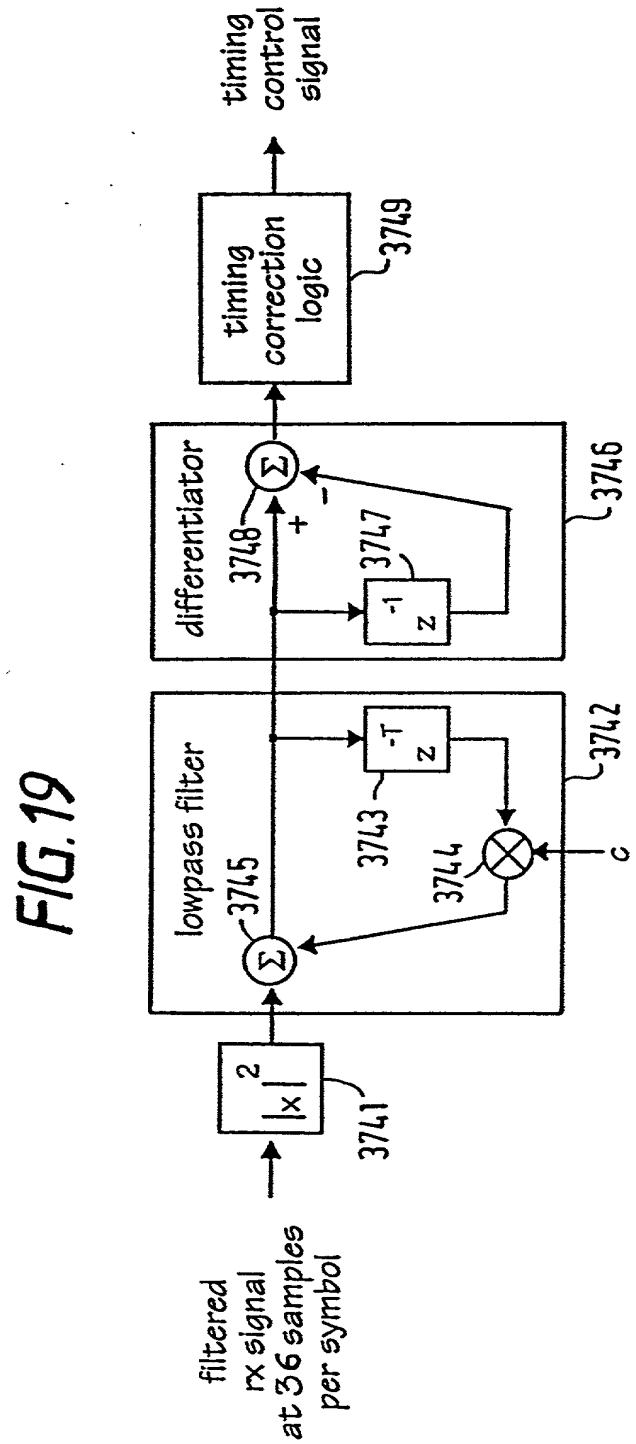

filtered rx signal at 36 samples per symbol
|x|²
3741
lowpass filter
3745
Σ
-T
z
3743
3744
c
3742
differentiator
3748
Σ
+
-
3747
-1
z
3746
timing correction logic
3749
timing control signal

FIG. 19

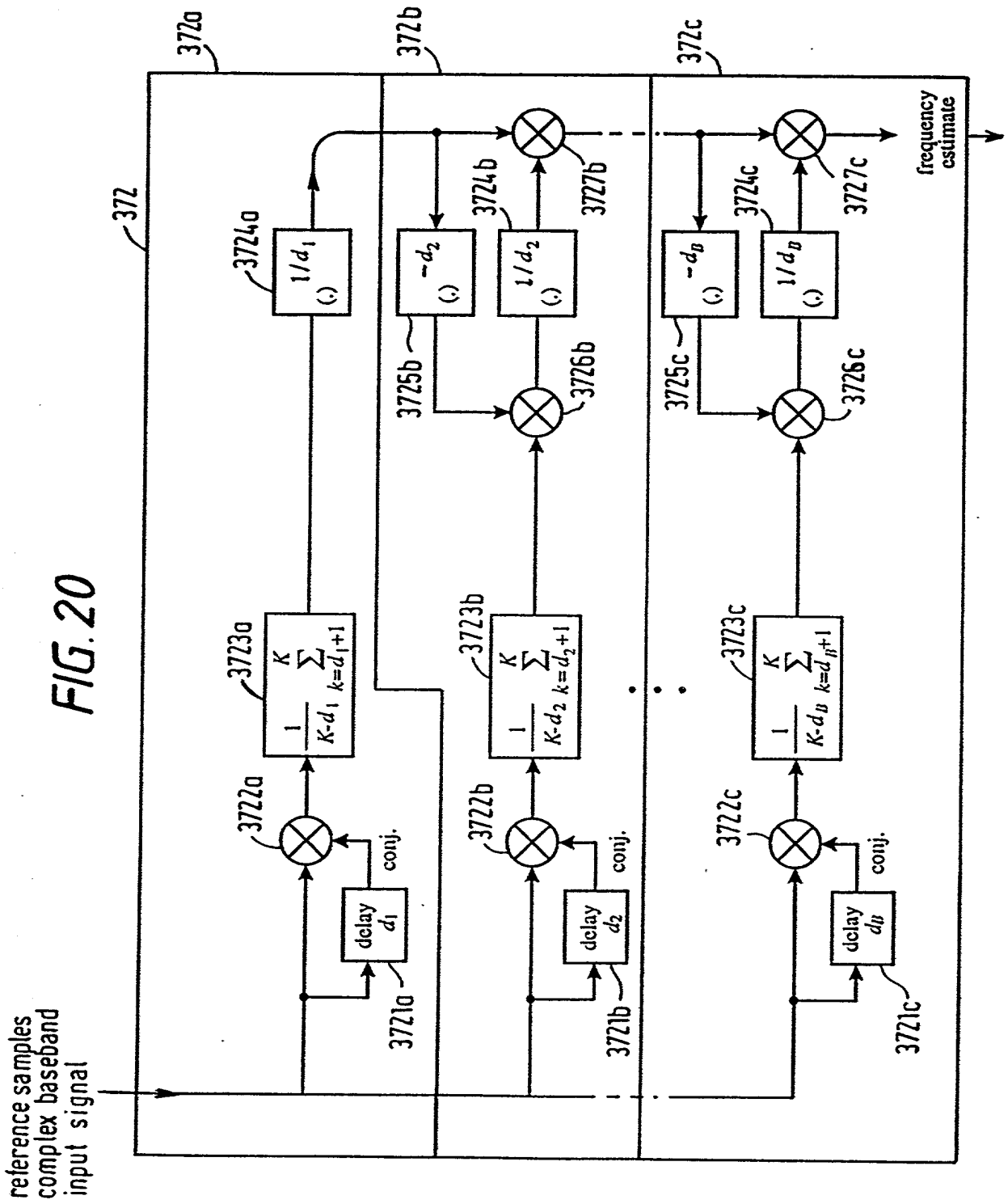

reference samples
complex baseband
input signal
372
372a
372b
372c
3721a
3721b
3721c
delay d_1
delay d_2
delay d_B
conj.
3722a
3722b
3722c
3723a
3723b
3723c
$\frac{1}{K-d_1}\sum_{k=d_1+1}^{K}$
$\frac{1}{K-d_2}\sum_{k=d_2+1}^{K}$
$\frac{1}{K-d_B}\sum_{k=d_B+1}^{K}$
3724a
3724b
3724c
$1/d_1$ (.)
$-d_2$ (.)
$1/d_2$ (.)
$-d_B$ (.)
$1/d_B$ (.)
3725b
3725c
3726b
3726c
3727b
3727c
frequency estimate

FIG. 20

FIG. 21

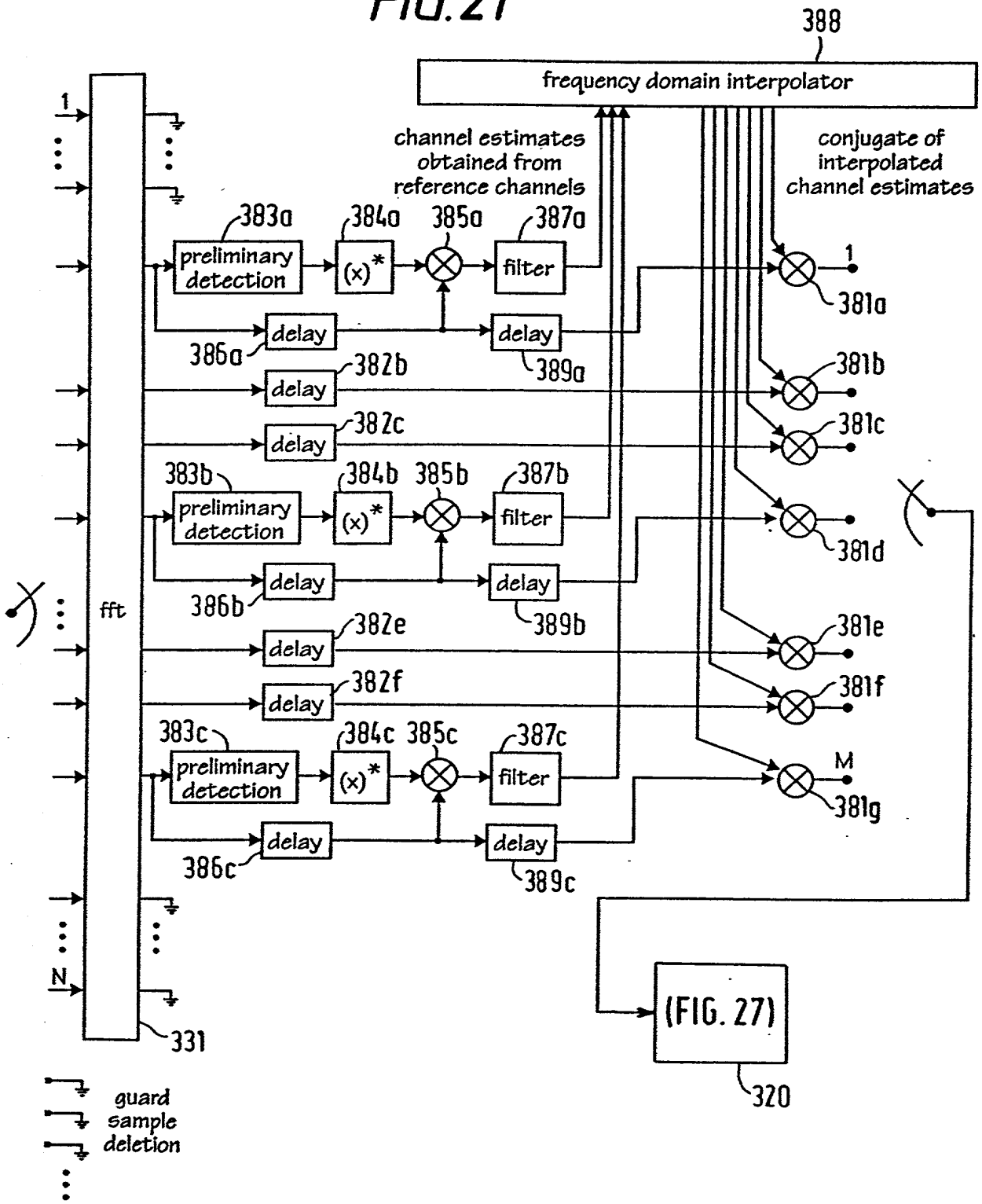

388
frequency domain interpolator
channel estimates obtained from reference channels
conjugate of interpolated channel estimates
1
N
fft
331
guard sample deletion
383a
preliminary detection
384a
(x)*
385a
filter
387a
delay
386a
delay
389a
382b
382c
383b
384b
385b
387b
386b
389b
382e
382f
383c
384c
385c
387c
386c
389c
381a
381b
381c
381d
381e
381f
M
381g
(FIG. 27)
320

FIG. 22

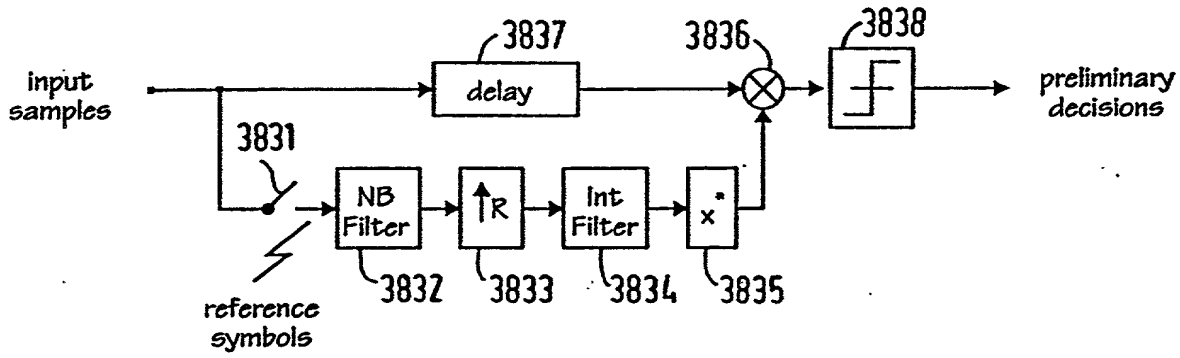
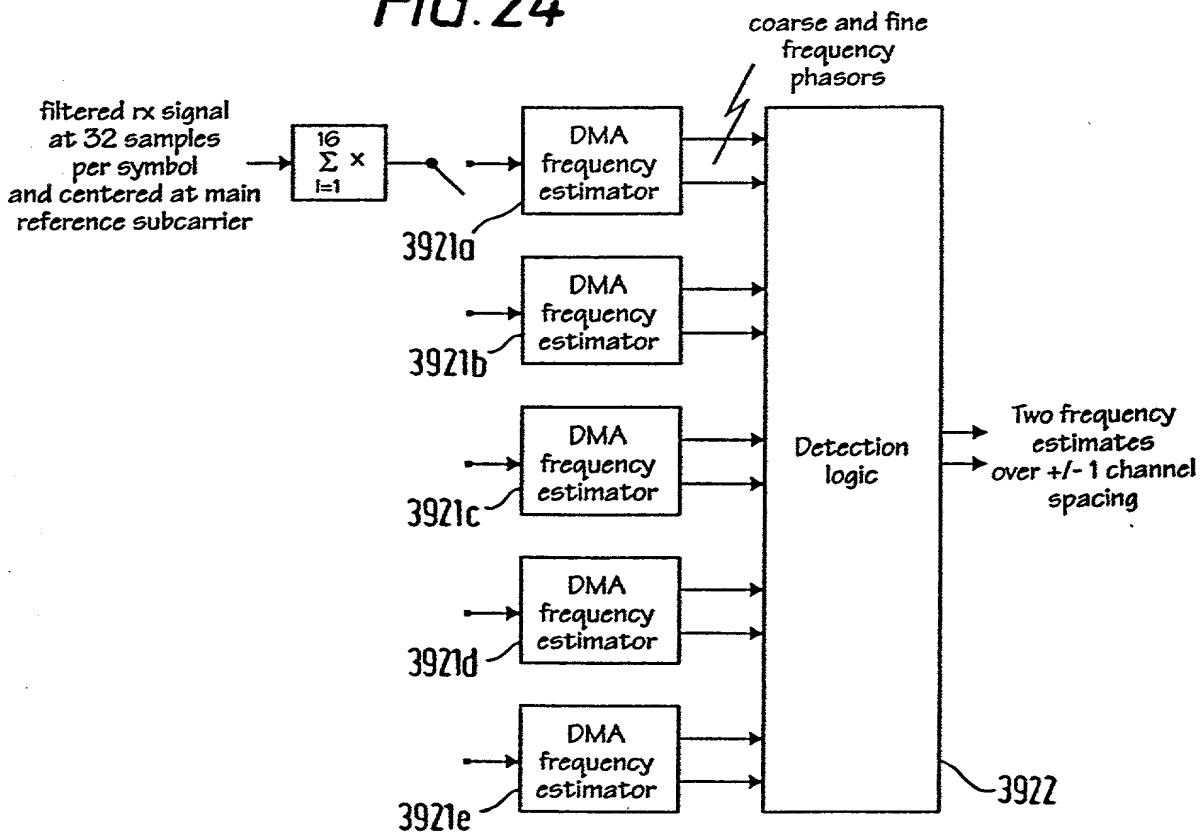

input samples
3837
delay
3836
3838
preliminary decisions
3831
NB Filter
R
Int Filter
x*
reference symbols
3832
3833
3834
3835

FIG. 24


coarse and fine frequency phasors
filtered rx signal at 32 samples per symbol and centered at main reference subcarrier
16 Σ x i=1
DMA frequency estimator
3921a
DMA frequency estimator
3921b
DMA frequency estimator
3921c
DMA frequency estimator
3921d
DMA frequency estimator
3921e
Detection logic
Two frequency estimates over +/- 1 channel spacing
3922

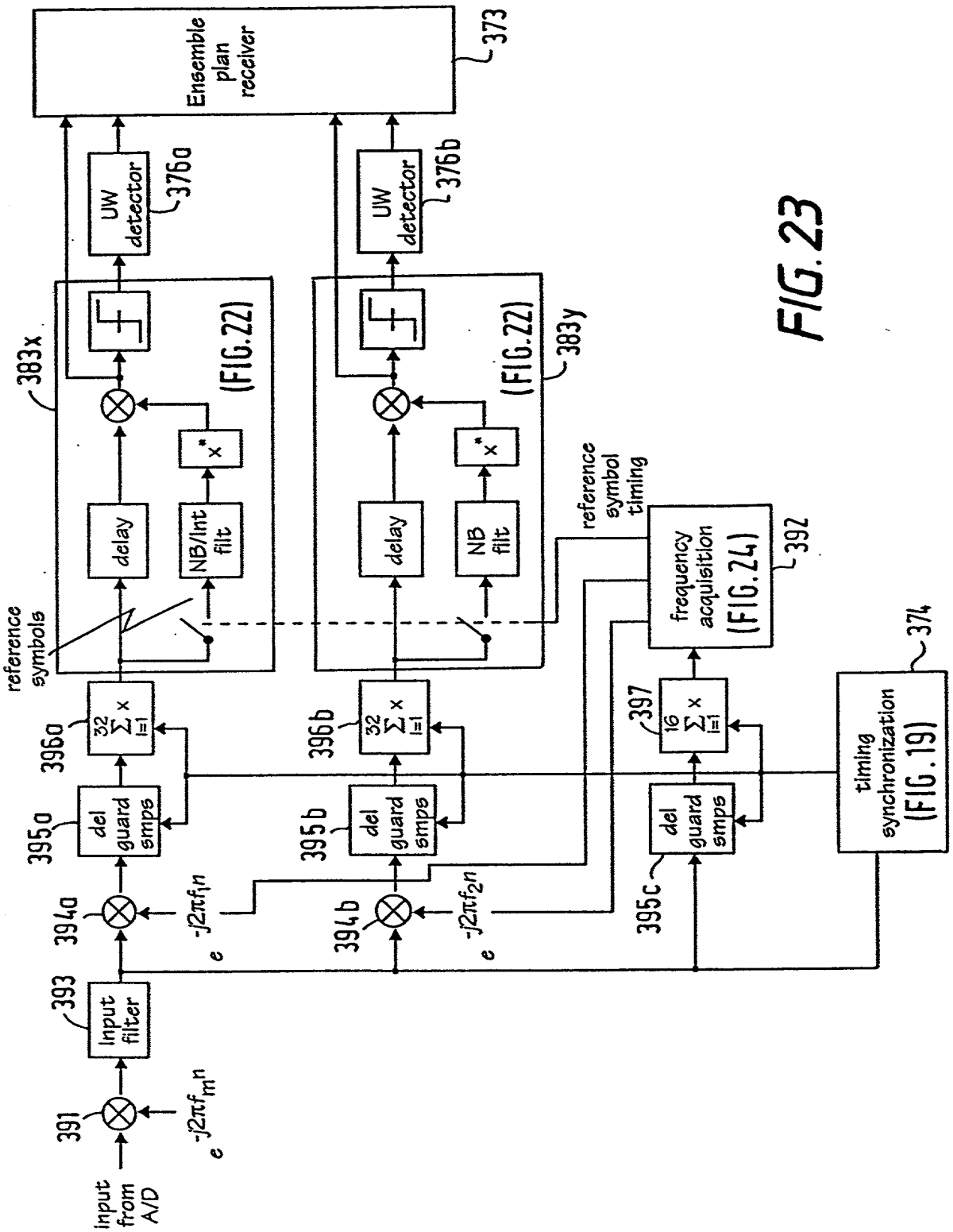

Input from A/D
391
$e^{-j2\pi f_m n}$
Input filter
393
394a
$e^{-j2\pi f_1 n}$
394b
$e^{-j2\pi f_2 n}$
395a
del guard smps
395b
del guard smps
395c
del guard smps
396a
$\sum_{i=1}^{32} x$
396b
$\sum_{i=1}^{32} x$
397
$\sum_{i=1}^{16} x$
reference symbols
delay
NB/Int filt
x^*
(FIG.22)
383x
delay
NB filt
x^*
(FIG.22)
383y
reference symbol timing
frequency acquisition (FIG.24)
392
timing synchronization (FIG.19)
374
UW detector
376a
UW detector
376b
Ensemble plan receiver
373

FIG.23

FIG. 25

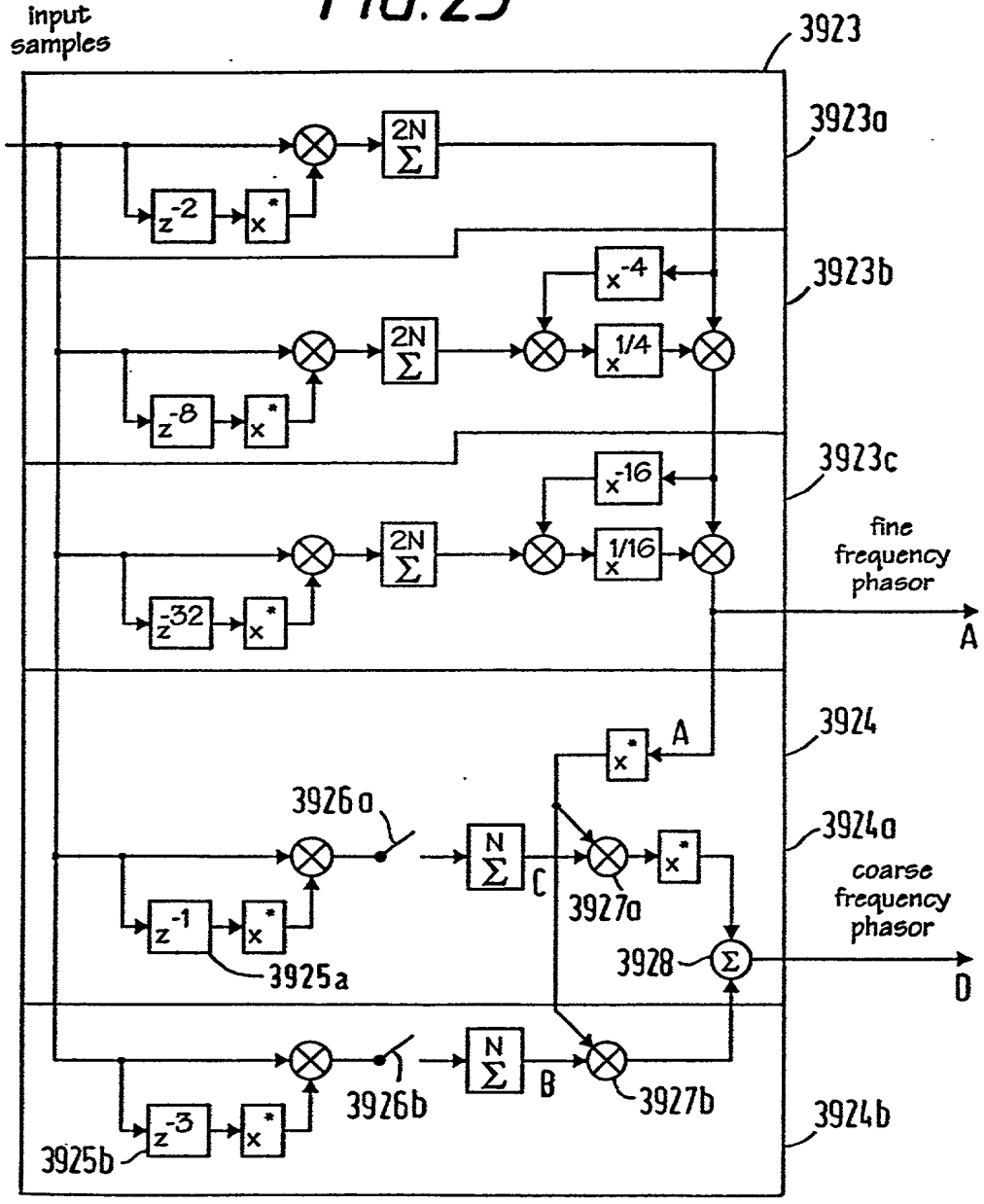
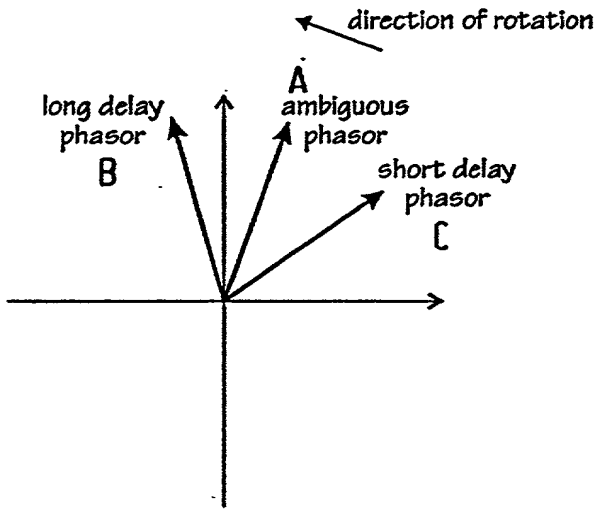
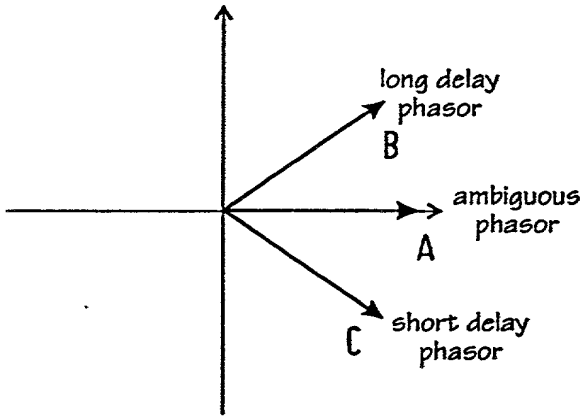

input samples
3923
3923a
3923b
3923c
3924
3924a
3924b
2N Σ
N Σ
z^{-2}
z^{-8}
z^{-32}
z^{-1}
z^{-3}
x^{-4}
x^{-16}
x 1/4
x 1/16
x*
3926a
3926b
3925a
3925b
3927a
3927b
3928
fine frequency phasor
coarse frequency phasor
A
B
C
D

FIG. 26

a) long and short delay phasors relative to the ambiguous phasor



b) long and short delay phasors after rotation by the ambiguous phasor



c) final unambiguous frequency phasor

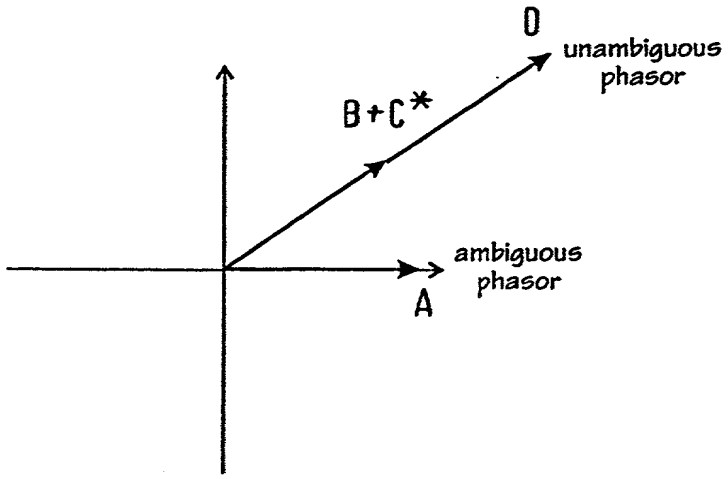
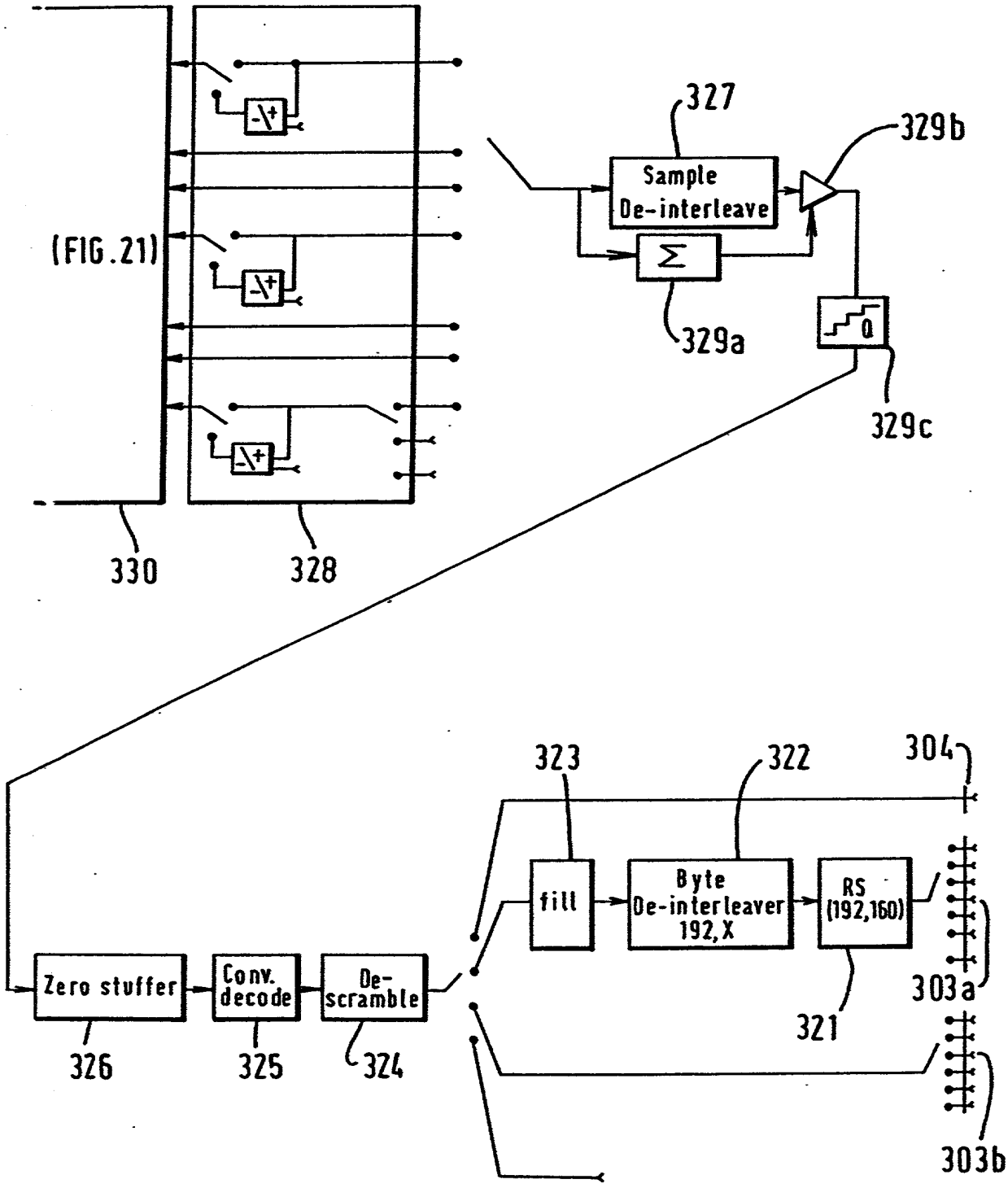


FIG. 27


(FIG. 21)
330
328
327
Sample
De-interleave
Σ
329a
329b
Q
329c
323
322
304
fill
Byte
De-interleaver
192, X
RS
(192,160)
303a
321
303b
Zero stuffer
Conv.
decode
De-
scramble
326
325
324

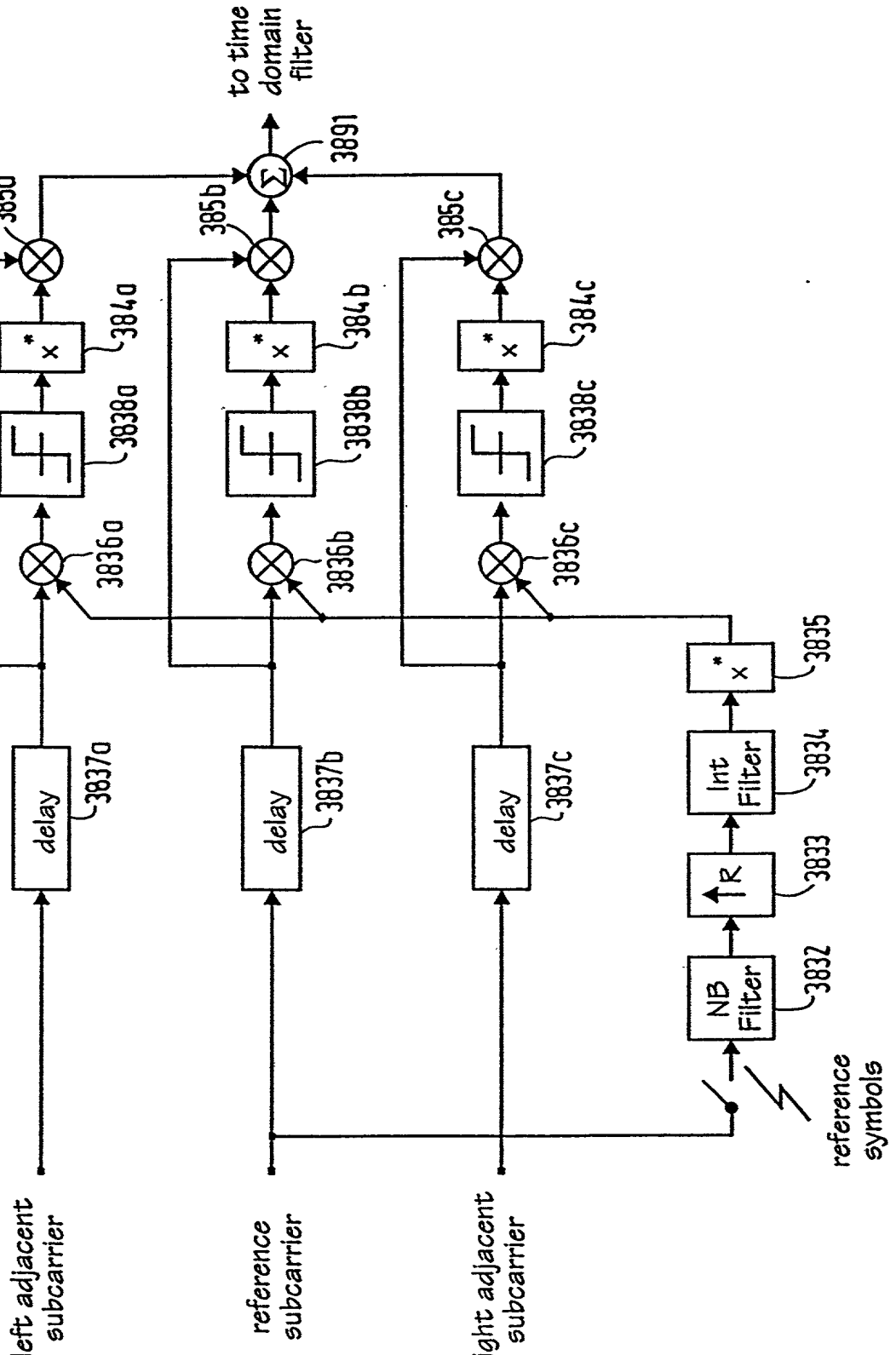
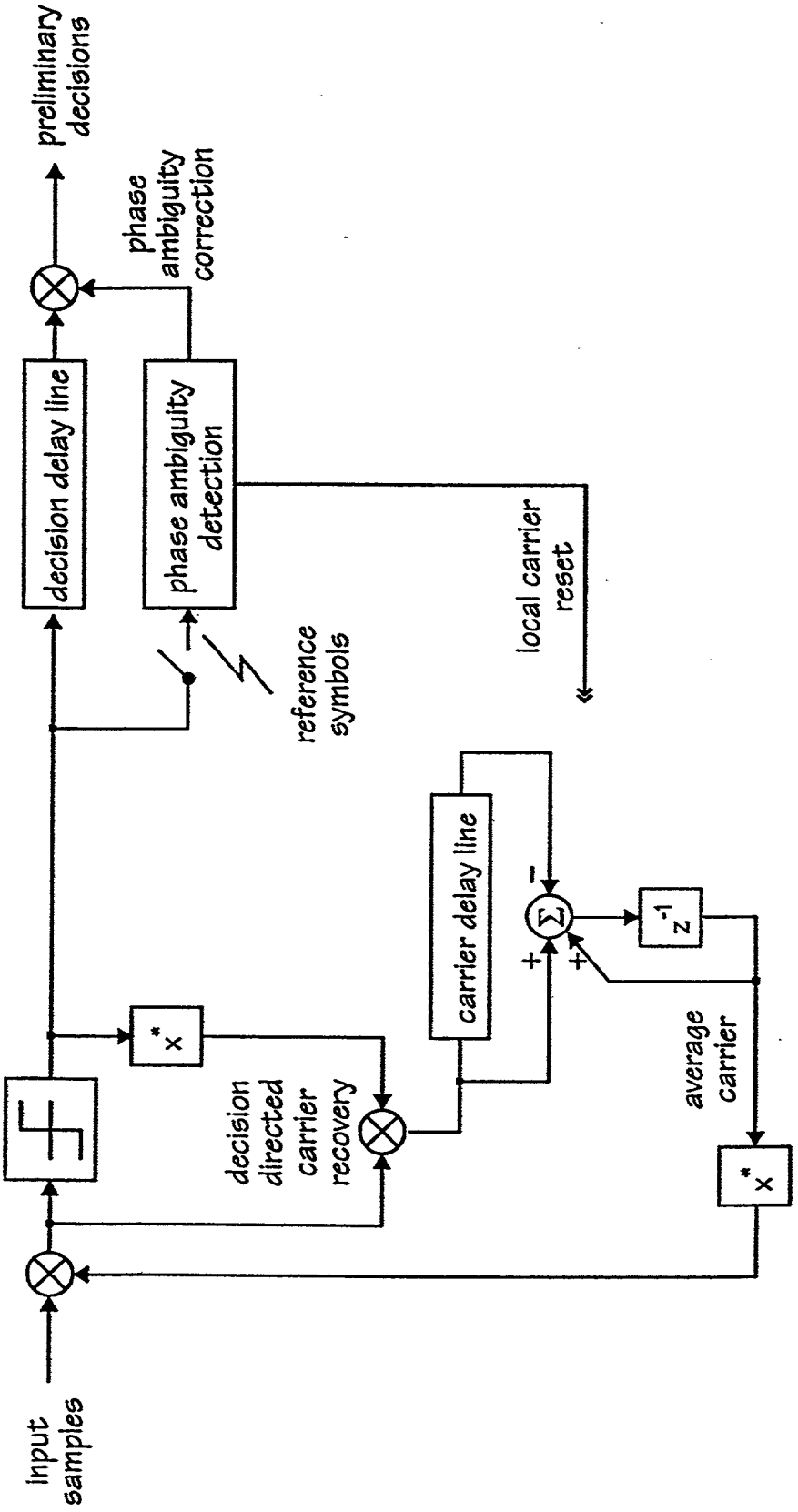

left adjacent subcarrier
reference subcarrier
right adjacent subcarrier
reference symbols
delay
3837a
delay
3837b
delay
3837c
NB Filter
3832
R
3833
Int Filter
3834
*
x
3835
3836a
3836b
3836c
3838a
3838b
3838c
384a
384b
384c
385a
385b
385c
3891
to time domain filter

FIG.28

FIGURE 6 CANADA

FIG. 29a



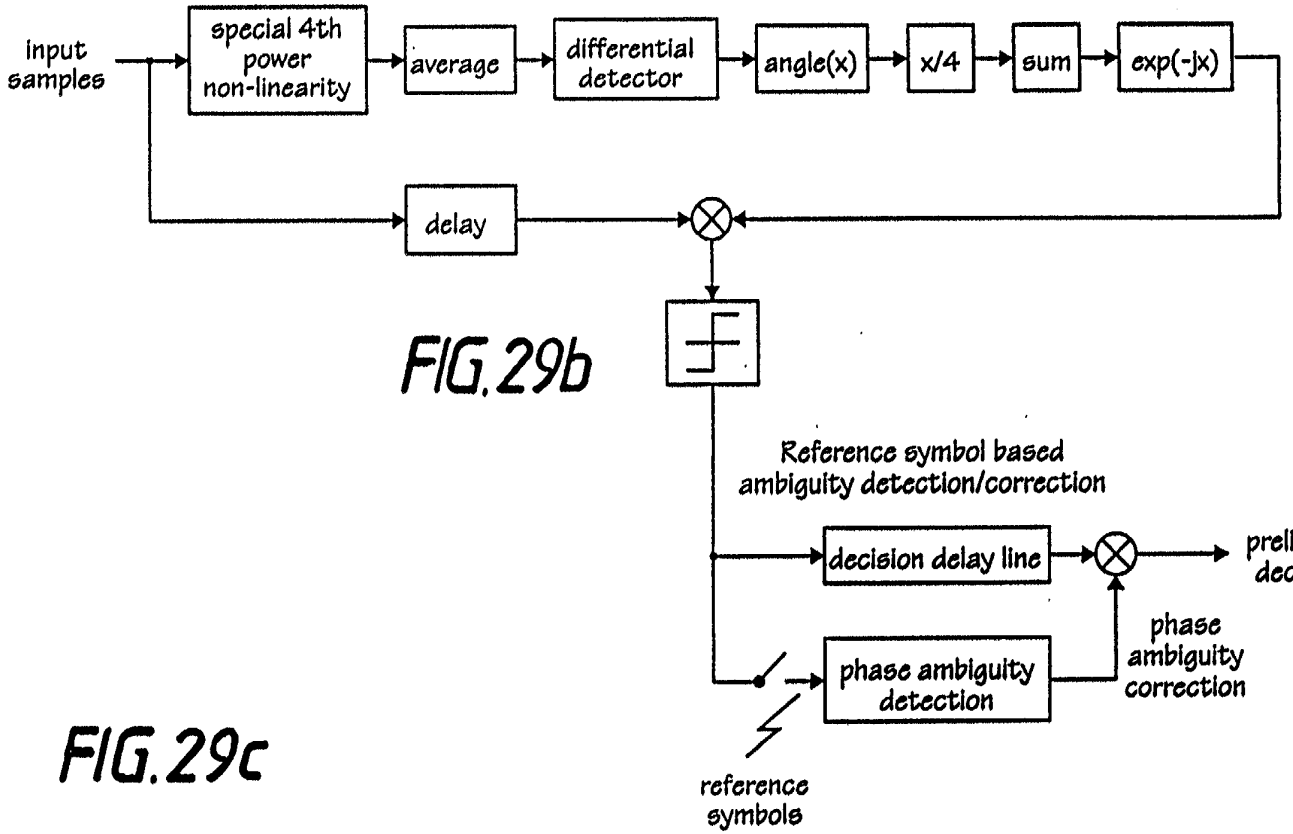


FIG. 29b

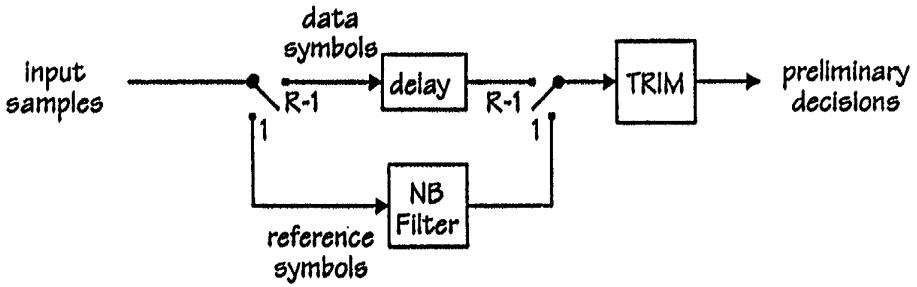



FIG. 29c